Proceedings of the I·R·E

APRIL 1939

VOLUME 27 NUMBER 4

Institute of Radio Engineers

Joint Meeting With American Section, International Scientific Radio Union

Washington, D. C., April 28 and 29, 1939

New York Meeting—Engineering Societies Building—May 3

33 West 39th Street, New York, N. Y.

National Convention

San Francisco, California, June 27–30, 1939

Fourteenth Annual Convention

New York, N. Y., September 20–23, 1929

SECTION MEETINGS

CLEVELAND April 27	**LOS ANGELES** April 18	**PITTSBURGH** April 18
DETROIT April 21	**PHILADELPHIA** May 4	**WASHINGTON** April 10

SECTIONS

ATLANTA—Chairman, Ben Akerman; Secretary, J. G. Preston, 230 Ansley St., Decatur, Ga.

BOSTON—Chairman, H. W. Lamson; Secretary, E. B. Dallin, 64 Oakland Ave., Arlington, Mass.

BUFFALO-NIAGARA—Chairman, H. C. Tittle; Secretary, E. C. Waud, 235 Huntington Ave., Buffalo, N. Y.

CHICAGO—Chairman, V. J. Andrew; Secretary, G. I. Martin, RCA Institutes, 1154 Merchandise Mart, Chicago, Ill.

CINCINNATI—Chairman, H. J. Tyzzer; Secretary, J. M. McDonald, Crosley Radio Corp., 1329 Arlington, Cincinnati, Ohio.

CLEVELAND—Chairman, S. E. Leonard; Secretary, Hollie C. Williams, Rm. 1932, 750 Huron Rd., Cleveland, Ohio.

CONNECTICUT VALLEY—Chairman, E. R. Sanders; Secretary, W. R. G. Baker, General Electric Co., Bridgeport, Conn.

DETROIT—Chairman, L. C. Smeby; Secretary, R. J. Schaefer, 9753 N. Martindale, Detroit, Mich.

EMPORIUM—Chairman, R. K. McClintock; Secretary, D. R. Kiser, Hygrade Sylvania Corp., Emporium, Penna.

INDIANAPOLIS—Chairman, C. F. Wolcott; Secretary, B. V. K. French, P. R. Mallory & Co., E. Washington, St., Indianapolis, Ind.

LOS ANGELES—Chairman, F. G. Albin; Secretary, M. T. Smith, General Radio Co., Seward & Romaine Sts., Hollywood, Calif

MONTREAL—Chairman, Sydney Sillitoe; Secretary, R. E. Hammond, 1261 Shearer St., Montreal, Que

NEW ORLEANS—Chairman, G. H. Pierce; Secretary, D. W. Bowman, 8327 Sycamore St., New Orleans, La.

PHILADELPHIA—Chairman, H. J. Schrader; Secertary, R. L. Snyder, 103 Franklin Rd., Glassboro, N. J.

PITTSBURGH—Chairman, W. P. Place; Secretary, R. E. Stark, 90 Pilgrim Rd., Rosslyn Farms, Carnegie, Penna.

PORTLAND—Chairman, H. C. Singleton; Secretary, E. R. Meissner, United Radio Supply, Inc., 203 S. W. Ninth Ave., Portland, Ore.

ROCHESTER—Chairman, H. J. Klumb; Secretary, H. C. Sheve, Stromberg-Carlson Telephone Manufacturing Co., Rochester, N. Y.

SAN FRANCISCO—Chairman, F. E. Terman; Secretary, L. J. Black, 243-30th St., Oakland, Calif.

SEATTLE—Chairman, R. O. Bach; Secretary, Karl Ellerbeck, Pacific Telephone and Telegraph Co., 612 Northern Life Tower, Seattle, Wash.

TORONTO—Chairman, R. C. Poulter; Secretary, N. Potter, Canadian National Carbon Co., Ltd., 805 Davenport Rd., Toronto, Ont.

WASHINGTON—Chairman, Gerald C. Gross; Secretary, M. H. Biser, Capitol Radio Engineering Institute, Riggs Bank Bldg., Washington, D. C.

Proceedings of the I·R·E

Published Monthly by
The Institute of Radio Engineers, Inc.

VOLUME 27 — *April, 1939* — NUMBER 4

Entered as second-class matter October 26, 1927, at the post office at Menasha, Wisconsin, under the Act of February 28, 1925, embodied in Paragraph 4, Section 412 of the Postal Laws and Regulations. Publication office, 450 Ahnaip Street, Menasha, Wisconsin. Subscription, $10.00 per year; foreign, $11.00.

THE INSTITUTE

The Institute of Radio Engineers serves those interested in radio and allied electrical-communication fields through the presentation and publication of technical material. In 1913 the first issue of the PROCEEDINGS appeared; it has been published uninterruptedly since then. Over 1500 technical papers have been included in its pages and portray a currently written history of developments in both theory and practice.

STANDARDS

In addition to the publication of submitted papers, many thousands of man-hours have been devoted to the preparation of standards useful to engineers. These comprise the general fields of terminology, graphical and literal symbols, and methods of testing and rating apparatus. Members receive a copy of each report. A list of the current issues of these reports follows:

Standards on Electroacoustics, 1938
Standards on Electronics, 1938
Standards on Radio Receivers, 1938
Standards on Radio Transmitters and Antennas, 1938.

MEETINGS

Meetings at which technical papers are presented are held in the twenty-one cities in the United States and Canada listed on the inside front cover of this issue. A number of special meetings are held annually and include one in Washington, D. C., in co-operation with the American Section of the International Scientific Radio Union (U.R.S.I.) in April, which is devoted to the general problems of wave propagation and measurement technique, the Rochester Fall Meeting in co-operation with the Radio Manufacturers Association in November, which is devoted chiefly to the problems of broadcast-receiver design, and the Annual Convention, the location and date of which is not fixed.

MEMBERSHIP

Membership has grown from a few dozen in 1912 to more than five thousand. Practically every country in the world in which radio engineers may be found is represented in our membership roster. Approximately a quarter of the membership is located outside of the United States. There are several grades of membership, depending on the qualifications of the applicant. Dues range between $3.00 per year for Students and $10.00 per year for Members. PROCEEDINGS are sent to each member without further payment.

PROCEEDINGS

The contents of each paper published in the PROCEEDINGS are the responsibility of the author and are not binding on the Institute or its members. Material appearing in the PROCEEDINGS may be reprinted or abstracted in other publications on the express condition that specific reference shall be made to its original appearance in the PROCEEDINGS. Illustrations of any variety may not be reproduced, however, without specific permission from the Institute.

Papers submitted to the Institute for publication shall be regarded as no longer confidential. They will be examined by the Papers Committee and Board of Editors to determine their suitability for publication. Suggestions on the mechanical form in which manuscripts should be prepared may be obtained from the Secretary.

SUBSCRIPTIONS

Annual subscription rates for the United States of America, its possessions, and Canada, $10.00; to college and public libraries when ordering direct, $5.00. Other countries, $1.00 additional.

The Institute of Radio Engineers, Inc.
Harold P. Westman, Secretary
330 West 42nd Street
New York, N.Y.

Receiver with Automatic Selectivity Control Responsive to Interference*

JOHN F. FARRINGTON†, FELLOW, I.R.E.

Summary—*The selectivity requirements of a broadcast receiver that must be met in order for it to perform satisfactorily under service conditions are discussed. A superheterodyne receiver is described that has its selectivity controlled automatically to meet these requirements. It has intermediate-frequency selectors in which vacuum tubes are used to adjust the coupling between tuned circuits to effect adjustment of the selectivity. The tubes are controlled by signal-derived potentials so that the band width increases in accordance with the strength of the desired signal and decreases in response to undesired signals on adjacent channels. As a result, the selectivity and the fidelity of the receiver are maintained at optimum under all conditions of signal strength and interference.*

Introduction

OUR broadcast stations transmit programs that include frequencies up to 8000 cycles. To reproduce these programs, a receiver must have broad selective circuits and a high-fidelity audio-frequency system. Most of the receivers on the market are designed primarily for reception through interference; therefore, they have sharp selector circuits. Users of such receivers never realize the benefits of the high-fidelity broadcasts. What the listener really should have is a receiver with adjustable selectivity so that he can receive properly the high-fidelity programs from local stations or receive to best advantage the weak stations.

But the problem is more complicated than this apparently, for adjustable selectivity receivers have been on the market for some time and yet they have not had a great appeal. It develops that interference and background noise determine the optimum relations between selectivity and the strength of the desired signals. The user of an adjustable selectivity receiver cannot be expected to know these optimum relations or to appreciate their importance. Consequently he cannot be expected to adjust his receiver correctly. The receiver he needs must be engineered so that it does the job properly for him.

The special problems involved in designing such a set will be discussed. A receiver that has its selectivity controlled automatically to best advantage by the strength of the desired signal and by the relation between the strengths of the desired and interfering signals will be described.

Special Requirements of Receiver

To obtain the full benefits and entertainment value from wide-frequency-range broadcasts, it is necessary to use a receiver that accepts the full range of modulation side-band frequencies without appreciable discrimination and handles satisfactorily the corresponding wide range of audio frequencies. There is a further requirement that the strength of the desired radio signal shall be well above the level of adjacent-channel interfering signals and of noise originating in the receiver and external thereto. When reception conditions are not favorable as regards interference and noise, the receiver band width must be reduced in order that signals may be received to best advantage.

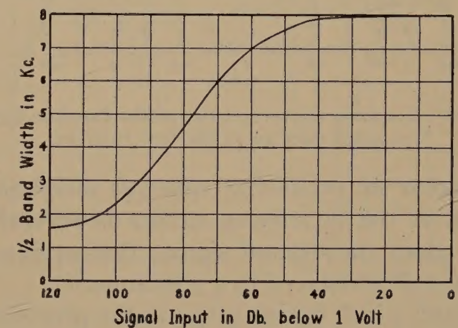


Fig. 1—Optimum receiver band width versus signal strength.

Before a receiver can be designed to provide these selectivity adjustments automatically, the optimum relations between receiver band width and signal strength must be known. To determine these, tests were made using an adjustable selectivity receiver.

Set noise of the hiss type, produced by tubes and circuits, was found to be a definite limitation. The curve of Fig. 1 shows the relation between the receiver band width and desired signal strength that gives a fair compromise between fidelity of reproduction and tolerable noise background of this character. However, a receiver that is adjusted in this manner will have somewhat greater background noise for weak signals than for strong signals.

When receiving in the presence of electrical disturbances originating external to the set, stronger desired-signal levels than those indicated by the curve are required for the various degrees of receiver band-width expansion, depending on the character and magnitude of the disturbances.

An interfering signal on a channel immediately adjacent to the desired signal also necessitates limiting the receiver band width in order to avoid cross talk

* Decimal classification: R361.2×R430. Original manuscript received by the Institute, July 12, 1938. Presented before I.R.E. Convention, New York, N. Y., June 16, 1938.
† Hazeltine Service Corporation, Bayside, L. I., N. Y.

and monkey chatter. Tests indicate that when the interfering signal strength is equal to the desired signal strength, the band width of the receiver should not exceed approximately 7000 cycles, that is, ±3500 cycles. This figure was determined by listening to interfering transmitters that were not overmodulated

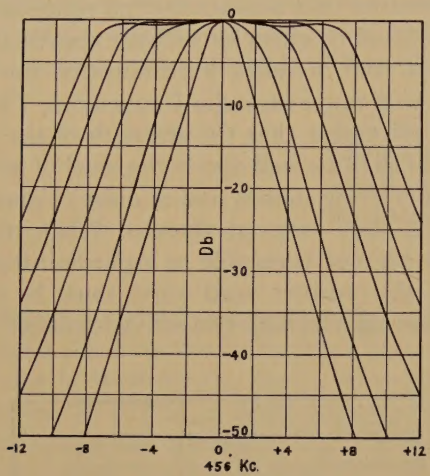


Fig. 2—Response characteristics of the intermediate-frequency selector of the test receiver.

to the point of producing spurious side-band frequencies. If the interfering carrier is several times stronger than the desired signal, the receiver band width should be reduced to a minimum.

The band-width figures given in the preceding discussion were obtained with a superheterodyne receiver having a fairly broad radio-frequency selector and an audio-frequency amplifier and loud speaker that handled efficiently frequencies out to 8000 cycles. The chief selectivity resided in the intermediate-frequency selector system. Its band width was continuously adjustable between limits of ±1600 cycles and ±8500 cycles by a manual control. Typical response characteristics of this selector are shown in Fig. 2. The band widths were measured at frequencies at which the output was one half the mid-band frequency response. The sensitivity of this receiver was about 2 microvolts and the noise about 0.5 microvolt at the minimum band-width adjustment of ±1600 cycles.

Design of Receiver

With these performance requirements as a guide, a superheterodyne receiver was produced that had the special features shown in the circuit diagram of Fig. 3. To simplify the explanation, the various special circuits are shown as independent of one another. Modifications that reduce the number of tubes are indicated later.

The signal circuit of the receiver includes a tunable radio-frequency selector-amplifier and frequency changer, a two-stage adjustable band-width intermediate-frequency amplifier, and a high-fidelity audio-frequency amplifier and associated sound reproducer. With the exception of the intermediate-frequency selector-amplifier, these components are of conventional design except that they handle efficiently modulation frequencies up to 8000 cycles.

Adjustable Band-Width Selector

The chief selectivity of the receiver resides in the adjustable band-width intermediate-frequency selector units. There are two of these and they are substantially identical. Each selector includes a pair of resonant circuits (p), tuned to the intermediate frequency of 455 kilocycles. These are coupled by two vacuum tubes, the intermediate-frequency amplifier tube that operates in the direction of travel of the signal through the receiver and the band-width control tube that operates to feed back energy from the output tuned circuit to the input tuned circuit of the amplifier tube. The coils that couple the feed-back tube to the selective circuits are poled so that the feedback is degenerative at the resonant frequency of the circuits and becomes regenerative as the frequency departs either way from the resonant frequency.

The coupling between the selective circuits that is effective in determining the band width of the se-

ASC Selector-Amplifier

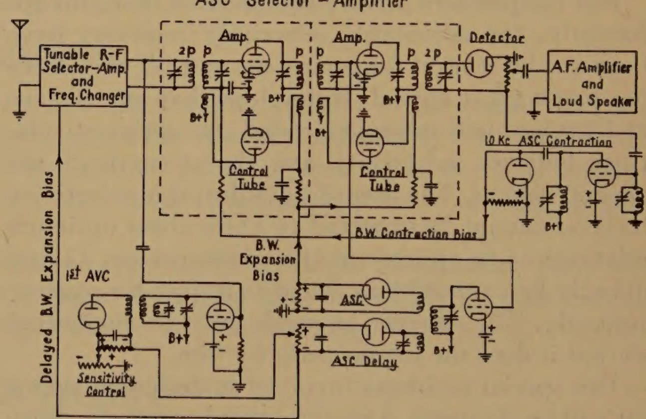


Fig. 3—Receiver with automatic selectivity control responsive to interference.

lector is proportional to the mean of the mutual conductances of the two tubes. Therefore, the transmission-frequency band of the selector can be regulated automatically by controlling the mutual conductances of these tubes with signal-derived bias potentials. This will be treated later.

In the absence of signal input to the receiver, the amplifier tube has a fixed normal-bias potential that produces its rated mutual conductance and the con-

trol tube has a fixed bias potential that reduces its mutual conductance substantially to zero. With these potentials on the tubes, the selector has a minimum band width determined by the power factors of the two tuned circuits, and the stage gain is a maximum. A positive control potential applied to the grid of the control tube will increase its mutual conductance so that it functions to broaden the band width of the selector and to reduce the gain through the stage, thus effecting both selectivity control and gain control. The algebraic sum of the grid potentials applied to the control tube should never be less than the rated negative potential.

The response characteristics of a single-stage selector as a function of the mutual conductance of the control tube are given in Fig. 4. The characteristics become double-peaked because of degenerative action produced by the control tube at the resonant frequency of the tuned circuits and regenerative action at the off-resonant frequencies. The gain is reduced by increasing the mutual conductance of the control tube, just as though the tuned circuits were detuned symmetrically.

To secure flat-top expansion characteristics in the selector system, a third tuned circuit ($2p$) is included as part of each stage. This tuned circuit has twice the power factor of the other two selective circuits. It is coupled loosely to one of the sharper circuits to avoid widening unduly the over-all selectivity. The resulting response characteristics of a three-circuit selector are shown in Fig. 5.

When the selector is operated in the expanded band-width condition by the application of a positive control potential to the control tube, the band width may be contracted by impressing a negative control potential on the amplifier tube to reduce its mutual conductance. Contraction of the band width in this manner does not affect materially the gain at the resonant frequency of the selector unless the band width is reduced below the condition corresponding to optimum coupling, when gain reduction becomes quite pronounced.

The two automatic-selectivity-control stages are connected in cascade by coupling the output tuned circuit of the first stage to the input tuned circuit of the second stage, using less than optimum coupling to avoid unnecessary widening of the selectivity characteristics.

Band-Width Control Circuits

Control of the adjustable intermediate-frequency selector-amplifier system to achieve the desired receiver operation is effected by the several control circuits shown in the diagram of Fig. 3.

For controlling the receiver band width in accordance with the strength of the desired signal, the automatic-selectivity-control diode is used to develop a signal-derived positive potential for actuating the control tubes. To insure band expansion in accordance with the curve of Fig. 1, adequate gain from the antenna to this diode must be provided. To prevent appreciable expansion of the band width for signals stronger than 5 or 10 millivolts, it is necessary to limit the amplitude of the intermediate-frequency carrier wave developed by the frequency converter and applied to the intermediate-frequency system. The *first automatic volume control* operating on the radio-frequency amplifier and on the frequency con-

Response Characteristics of an ASC Selector-Amplifier Stage

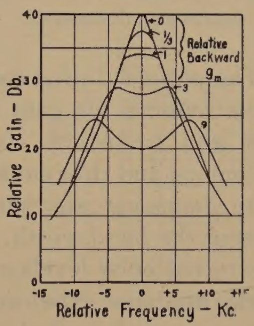


Fig. 4—Using two p circuits only.

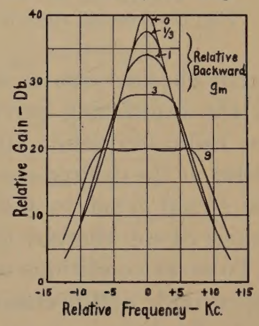


Fig. 5—Including $2p$ compensating circuit.

verter tubes accomplishes this. The gain between the antenna and the *first automatic volume control* diode is adjusted so that the control is effective only for signals greater than 1 millivolt.

Contraction of the receiver band width in the presence of a strong interfering signal on a channel adjacent to the desired signal wave is effected by the *10-kilocycle contraction control*. A negative control potential developed by the 10-kilocycle diode is applied to one or more of the amplifier tubes of the intermediate-frequency selector system. This potential is derived from the 10-kilocycle wave that is produced by the signal detector when the interfering and desired carrier waves are both present. The 10-kilocycle wave is selected from the audio-frequency output by circuits sharply resonant to this frequency. The control potential thus is substantially unaffected by side-band signal components associated with the desired carrier wave, so spurious operation does not occur when high-frequency modulation components of large amplitude are present. The take-off point for the 10-kilocycle wave precedes the audio-frequency volume control in order that the action will not be affected by volume-level adjustments. A reasonable amount of gain at 10 kilocycles is provided so that

the control will operate even when the intermediate-frequency selector system is contracted sufficiently to provide considerable attenuation of the adjacent-channel interfering carrier wave.

Additional band-width contraction by an interfering signal also is obtained from the *first automatic volume control* when the selective circuits associated with it are made broad enough to accept the adjacent-channel carrier wave. The potential produced by the interfering carrier wave reduces the gain of the radio-frequency amplifier and frequency converter at the desired-signal frequency and thus causes the signal level to fall at the *automatic-selectivity-control* diode, thereby contracting the band width.

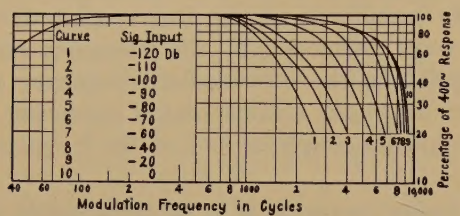


Fig. 6—Over-all electric fidelity versus signal strength.

To meet conditions where external noise levels are appreciable and necessitate delaying band expansion until the desired-signal level is greater than that required in the presence of set noise alone, additional controls are required. Two methods of accomplishing the desired results are shown in the receiver diagram.

The *sensitivity control* delays the band expansion by a definite amount. This control takes the form of a manually adjustable negative bias potential that is applied to the grids of the radio-frequency amplifier and frequency-changer tubes. Alternatively a positive potential may be applied in the cathode circuits of these tubes. By increasing the bias potential the sensitivity of the receiver is reduced so that stronger signals are required to produce a given intermediate-frequency output from the frequency changer, and consequently the expansion of the intermediate-frequency selector system is delayed. When external noise is consistently present, this form of control meets service conditions since it is futile to attempt to use a highly sensitive receiver in a noisy location.

In locations where noise is intermittent, the user of the receiver may forget to cut out the sensitivity control when the noise is not present, and thus fail to hear acceptable weak signals. To meet this condition a signal-derived negative bias potential may be obtained from the *automatic-selectivity-control delay* diode and applied to the radio-frequency amplifier and frequency changer to delay the expansion. The amount of delay may be regulated by the potentiometer to suit particular conditions. This arrangement leaves the sensitivity of the receiver unaffected, since the bias is nil when the signals are weak.

Over-All Performance Characteristics

Interesting performance characteristics of this receiver are shown in the following figures by curves based on over-all electrical fidelity measurements that are indicative of the performance of the automatic-selectivity-control system in regulating the receiver band width.

Electrical Fidelity Curves

Fig. 6 shows over-all electrical fidelity curves obtained at various levels of desired-signal strength; the sensitivity controls being inoperative and interfering signals being nil. It will be observed that the fidelity improves gradually with increasing signal strength until nearly the maximum is reached at approximately 3000 microvolts input, and that for signals above this level the fidelity remains substantially constant. Since in this receiver the frequency characteristic of the audio-frequency system was flat beyond 8000 cycles, the fidelity curves show substantially the performance of the adjustable-band-width selector system.

Effect of Interfering Signal

In Fig. 7 are curves showing the band width and the fidelity of the receiver as affected by an interfering signal on an adjacent channel. The ordinates of these curves are the fidelity as determined by the frequency at which the audio-frequency output is one half the 400-cycle output. Also they are one half

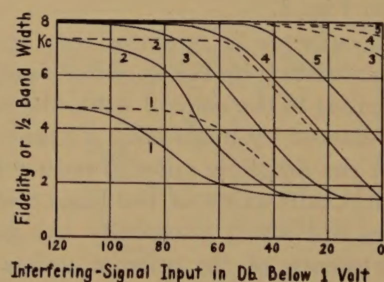


Fig. 7—Effect of adjacent-channel interfering signal on the contracting band width.

Curve	Desired-signal input Decibels below 1 volt
1	80
2	60
3	40
4	20
5	0

Solid curves
10-kilocycle automatic selectivity control and first automatic volume control operating.
Dash curves
10-kilocycle automatic selectivity control not in use.

of the receiver band width as measured at half the resonant-frequency response. Each curve has as a fixed parameter the strength of the desired signal, and as the variable the strength of an interfering signal 10 kilocycles removed from the desired signal.

The solid-line curves are with the *10-kilocycle* and *first automatic volume controls* operating. When the interfering signal is weak the band width of the receiver is unaffected by the interference. The terminal points of the several curves for the various levels of desired-signal strength indicate the normal band width of the receiver in the absence of interference. As the interfering-signal strength increases the band width of the receiver is reduced. When the interfering-signal strength is equal to the desired signal strength, the receiver band width is cut to approximately ± 3500 cycles. This meets the performance requirements determined by the preliminary investigation. Further increase in the interfering signal reduces the band width still more until it reaches the minimum value of about ± 1600 cycles, which is the limit of contraction procurable in this receiver. This performance is deemed satisfactory.

The dotted curves in the figure show the action of the *first automatic volume control* alone. The contraction produced by the interfering signal is much less pronounced and does not meet sufficiently well the requirements as previously outlined.

The importance of the *10-kilocycle control* is apparent.

Effect of Band-Expansion Delay Controls

The action obtained with the band-expansion delay controls is illustrated by the curves of Fig. 8. The ordinates are the same as in Fig. 7.

Curve *A* shows the normal performance without the controls. It approaches quite closely the preferred characteristic determined from the preliminary experiments with the manually controlled adjustable-selectivity receiver.

Curves *B* and *C* respectively show the effect of the *sensitivity control* and of the *automatic selectivity delay control*. The *sensitivity control* delays the band expansion by a definite amount throughout the entire range of desired-signal strength. The *automatic selectivity delay control* retards the expansion in a somewhat less desirable manner. The effect at low signal levels is not as good and the band widths obtained for strong signals are limited unnecessarily.

Both controls have advantages and disadvantages. They provide for a wide variety of reception conditions. Probably only one control is necessary to meet most operating requirements.

Tuning Characteristics

In tuning the receiver to a steady strong signal an effect somewhat like automatic-frequency-control action is obtained. As the receiver is brought near the desired signal, the adjustable-selectivity circuits operate to expand the receiver band width toward the signal with the result that over a reasonable tuning range the signal is heard clearly.

When receiving fading signals it is important that the set be tuned properly to the desired signal in order that distortion of the audio-frequency signal will not be produced by the carrier falling on the side of the selectivity characteristic as the band width contracts with the fading signal. On this account either automatic frequency control or a selective tuning indicator is a desirable element in the receiver.

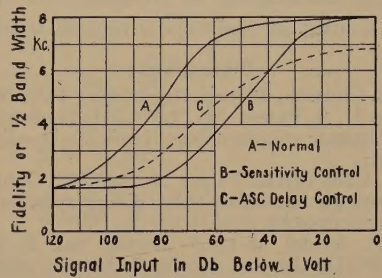


Fig. 8—Effect of controls for delaying expansion.

When tuning the receiver in the presence of adjacent-channel interfering signals, the 10-kilocycle band-contraction control is a definite tuning aid in that it serves to reduce the receiver output when the set is tuned between stations. This action takes place because between stations the 10-kilocycle beat note is greatest and consequently it produces a substantial contraction of the band width of the intermediate-frequency selectors and a marked reduction of the gain through them.

Design Simplifications

It is practicable to build a receiver having the desired special operating characteristics without employing as many tubes for the adjustable-selectivity selectors and their control circuits as were shown in the diagram of Fig. 3.

For example, the two control tubes used in the intermediate-frequency selectors can be triodes contained in one envelope. A 6N7 tube is satisfactory for this purpose. It is even possible to build an adjustable-band-width selector using only the intermediate-frequency amplifier tube, although the selector then is somewhat critical to adjust initially.

A 6B8 tube can be used simultaneously as the first automatic-volume-control intermediate-frequency

amplifier and rectifier and as the 10-kilocycle amplifier and rectifier without trouble.

Other savings in tube complement can be effected by taking the intermediate-frequency energy for the *automatic-selectivity-control* diode and for the *automatic-selectivity-control delay* diode from the output of the intermediate-frequency system.

If the *automatic-selectivity delay control* is not used, this saves a diode.

Such simplifications have been carried out successfully in practice.

Acknowledgment

The circuit for procuring adjustable selectivity control by feedback and the 10-kilocycle beat-note interference control were suggested by my associate, Mr. H. A. Wheeler. It is desired also to acknowledge the valuable assistance of Messrs. W. B. Wilkens and R. B. Brunn in the experimental work.

Bibliography

(1) K. A. Chittick, British Patent No. 445,030; September 30, 1933; also U. S. Patent No. 2,094,231; September 28, 1937. (Multiple automatic volume control individual to different stages of the receiver.)

(2) H. D. Ellis, British Patent No. 442,685; October 11, 1934. (Feedback through backward tube, giving symmetrical double-peak resonance curve.)

(3) "G. E. Model M-125," *Service*, vol. 3, pp. 422–425; November, (1934). (Double automatic volume control.)

(4) A. W. Martin, British Patent No. 448,716; January 23, 1935. (Automatic tone control responsive to adjacent-channel carrier, ±9 kilocycles.)

(5) N. R. Bligh and E. N. Smyth, British Patent No. 451,227; January 31, 1935. (Automatic selectivity control responsive to adjacent-channel carrier, ±9 kilocycles.)

(6) British Patent No. 450,081; April 13, 1935. (Automatic selectivity control responsive to adjacent-channel carrier, ±9 kilocycles, or to beat note of audio frequency above 6 kilocycles.)

(7) H. A. Wheeler and J. K. Johnson, "High fidelity receivers with expanding selectors," Proc. I.R.E., vol. 23, pp. 594–609; June, (1935). (Expansion of band width by variation of coupling between two p circuits, and leveling by a $2p$ third circuit.)

(8) British Patent No. 470,373; January 22, 1936. (Automatic selectivity control responsive to carrier beat note of high audio frequency.)

(9) L. F. Curtis, U. S. Patent No. 2,033,330; March 10, 1936. (Automatic selectivity control by feedback through backward tube, giving symmetrical double-peak resonance curve.)

(10) H. F. Mayer, "Automatic selectivity control," *Electronics*, vol. 9, pp. 32–34; December, (1936). (Automatic selectivity control by feedback through backward tube, giving symmetrical double-peak resonance curve.)

(11) Ho-Shou Loh, "On single and coupled circuits having constant response band characteristics," Proc. I.R.E., vol. 26, pp. 469–474; April, (1938). (More data on two coupled p circuits and one $2p$ circuit.)

(12) L. A. Moxon, British Patent No. 462,832; September 18, 1935. (Automatic selectivity control responsive to adjacent-channel carrier beat note of 9 kilocycles.)

(13) J. F. Farrington, British Patent No. 479,991; June 12, 1936. (Automatic selectivity control responsive to adjacent-channel carriers, ±10 kilocycles.)

(14) H. M. Lewis, British Patent No. 483,602; March 21, 1936. (Feedback through backward tube, giving symmetrical double-peak resonance curve.)

(15) H. A. Wheeler, British Patent No. 484,137; July 21, 1936. (Feedback through backward tube, giving symmetrical double-peak resonance curve.)

Radiotelephone System for Harbor and Coastal Services*

C. N. ANDERSON†, FELLOW, I.R.E., AND H. M. PRUDEN†, NONMEMBER, I.R.E.

Summary—*Radiotelephone service with harbor and coastal vessels is now being given through coastal stations in the vicinities of seven large harbors on the Atlantic and Pacific coasts with additional stations planned. The system is designed to be as simple as possible from both the technical and operating standpoints on both ship and shore.*

Recent developments in the shore-station design eliminates all manipulations of the controls by the technical operator. This is made possible principally because of crystal-controlled frequencies on shore and ship, a "vogad" which keeps the transmitting volume of the shore subscriber constant, and a "codan" incorporated in the shore radio receiver which will operate on signal carrier but is highly discriminatory against noise. A signaling system permits the traffic operator to call in an individual boat by dialing the assigned code which rings a bell on the particular boat called. The ship calls the shore station by turning on the transmitter. The radio signal operates the codan in the shore receiver which in turn lights a signal lamp in the traffic switchboard.

Gradually the system has been taking on more and more the aspects of the wire telephone system.

SOON after radiotelephone service for transoceanic ships was inaugurated[1,2] in December, 1929, steps were taken to establish a supplemental service for harbor craft and coastal vessels. In 1933, radio representatives of the United States and Canadian governments agreed to a tentative plan for frequency and location of stations to provide service for the Atlantic, Pacific, Gulf, and Great Lakes. This plan called for United States stations

Fig. 1—System of radiotelephone shore stations for United States coastal service.

located near the harbors of Boston, New York, Norfolk, Charleston, Miami, St. Petersburg, New Orleans, Galveston, Los Angeles, San Francisco, Astoria, and Seattle. Fig. 1 shows the estimated service ranges of stations so located, taking into consideration the smaller ranges of the southern stations because of increased radio noise. The solid lines indicate the Bell System stations now in service, namely, Boston, New York (two stations), Norfolk, Miami, Los Angeles, San Francisco, and Seattle.

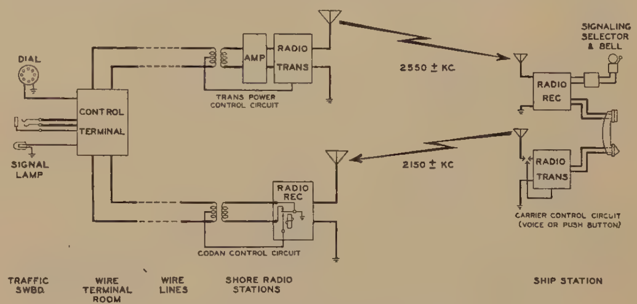


Fig. 2—General system schematic for harbor and coastal radiotelephone service.

Service to harbor and coastal vessels presents certain unique requirements which the system has been designed to meet. In the first place, the service is principally local with relatively few vessels venturing more than two or three hundred miles from shore so that the service area of any one station can be restricted. Second, the bulk of the potential service is with small vessels with limited space and personnel. Furthermore this type of vessel requires that the service be inexpensive. All of these requirements pointed to one main consideration: to make the system as simple as possible from both the technical and operating standpoints on both ship and shore.

The system for any one station (Fig. 2) consists, in general, of a shore radio transmitter, one or more shore radio receivers, wire lines extending back to a telephone toll office, the control and combining equipment, and the traffic switchboard for connecting the radio circuit to the wire telephone network. The ship stations consist, in general, of a radio transmitter, a radio receiver, a handset, possibly a small control unit and, in some cases, a selective-signaling selector. In many respects, the operation of the system appears to the subscribers quite similar to the land telephone system. The shore subscriber is generally unaware that he is speaking over a special circuit. With some ship equipments, a bell rings

* Decimal classification: R510. Original manuscript received by the Institute, June 10, 1938. Presented, I.R.E. Convention, New York, N. Y., June 18, 1938.

† Bell Telephone Laboratories, Inc., New York, N. Y.

[1] W. Wilson and L. Espenschied, "Radiotelephone service to ships at sea," *Bell Sys. Tech. Jour.*, vol. 9, pp. 407–428; July, (1930).

[2] C. N. Anderson and I. E. Lattimer, "Operation of a ship-shore radiotelephone system," Proc. I.R.E., vol. 20, pp. 407–433; March, (1932).

when the ship subscriber is wanted on the phone and lifting his handset off the hook puts his equipment in operation.

This paper discusses some of the fundamental technical considerations involved in the system design and the steps leading up to improved equipment requiring minimum manipulation on the part of the technical operator.

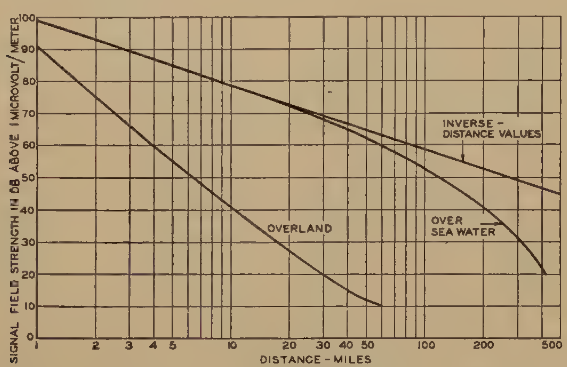


Fig. 3—Comparison of overland and overwater radio transmission, Green Harbor, Massachusetts. Frequency, 2590 kilocycles, radiated power, 200 watts.

Frequency Considerations

One of the earliest considerations in planning the harbor and coastal service was that of frequencies to be employed. As early as 1926, the Bell Telephone Laboratories made a rather elaborate survey of New York Harbor on various frequencies from 1500 to 12,000 kilocycles. By 1930, however, the utility of various frequencies for various types of services was fairly well established and indicated that for the limited ranges required, the most satisfactory frequencies lay between two and three megacycles. Ground-wave transmission on these frequencies provides reasonably reliable transmission over entire salt-water paths out to about three hundred miles. Also, daytime noise is lower in this frequency range than on either higher or lower frequencies. The present plan of the Federal Communications Commission provides for ten 8-kilocycle ship-to-shore channels between 2108 and 2208 kilocycles and ten shore-to-ship channels between 2504 and 2600 kilocycles. In addition, a ship-to-ship communication channel is provided on 2738 kilocycles.

One ship-to-shore channel frequency and one shore-to-ship frequency is assigned to each shore station and such vessels as work more than one shore station have to change their transmitting and receiving frequencies. This is no particular disadvantage as far as equipment for those vessels is concerned as present sets provide a multifrequency arrangement. However, the limiting factor in expediting service is the shore station. With the shore channel frequencies fixed, the waste of time incurred in shifting frequencies is eliminated, the shore radio transmitter is simpler, only one receiving frequency need be monitored on shore which is especially important when a plurality of shore receivers are used, and the radio equipments on shore and ship are always lined up without any question as to frequency. In addition, interference from other stations is avoided, advantage can be taken of geographical spacing to avoid interference between stations on adjacent channel frequencies, and ship-to-ship calls can be handled through the shore station with the latter acting as a repeater.

Transmission Considerations

The transmission range on a given frequency is primarily dependent on three factors, namely, type of transmission path, radio noise conditions, and the radiated transmitter power. Some idea of the effect of the type of path upon radio transmission may be had from Fig. 3, showing the signal fields obtained from a single vertical antenna at the Boston station at Green Harbor, Massachusetts, for overwater and overland paths. The attenuation over sea water differs from the inverse-distance values by only 0.06 decibel per mile whereas the fields, even for the first mile of overland transmission, are attenuated 9 or 10

Fig. 4—Radiotelephone shore station at Seattle, Washington.

decibels. At 10 miles, the difference between overland and overwater fields is nearly 40 decibels, a ratio of 100 to 1. Beyond 40 or 50 miles, sky-wave transmission tends to raise the overland field somewhat, thereby decreasing the differential. It is evident that the shore stations should be located so as to avoid land in the transmission paths, particularly near the radio terminals. Consequently, all the shore radio stations, both transmitting and receiving, are

located at or near the water's edge. This is illustrated by the Seattle, Washington, station shown in Fig. 4.

Radio noise may be classed as natural, commonly called static or atmospherics, and industrial. Fig. 5 shows the diurnal variation in static in terms of the signal field required for a commercial circuit. In the daytime, signal fields of only one or two microvolts per meter (0–6 decibels above 1 microvolt per meter) may be satisfactory for commercial circuits whereas at night, fields of 30 decibels above 1 microvolt per meter or more may be necessary. Although static cannot be avoided, much can be done to avoid industrial noise. In order not to penalize service unduly or limit the service range during the daytime when static is low, the receiving location should be as free from industrial noise as possible. For rural sections this is not difficult, but inasmuch as an important part of the service area is usually a busy harbor, the radio stations must often be located in an urban section. At all the stations, noise surveys were made before final selection to insure satisfactory daytime service with fields at least as low as 15 decibels above 1 microvolt per meter. In most cases, conditions are materially better than that.

A 50-watt boat set radiating 10 watts will give a field of 15 decibels above 1 microvolt per meter at a distance entirely over sea water of about 300 miles. For a 15-watt set radiating 1 watt, this distance is reduced to about 200 miles and for a 400-watt transmitter radiating 200 watts, the distance is increased to 450 miles. These figures give the order of daytime over-sea-water ranges which might be expected and are fairly reliably attained. At certain times of day, particularly in the early evening when the signal sky wave has materially increased and before the noise has reached its maximum, these ranges may occasionally be doubled or even tripled. On the other hand, when land constitutes a substantial portion of the transmission path, the transmission range may be reduced to the order of 10 miles for the 15-watt set and to 50 miles for the 400-watt set.

Ship-Station Requirements

As explained previously there are three important considerations regarding this service from the standpoint of the large bulk of the potential users which affect the ship-set design, namely, range, available space aboard ship, and simplicity of operation.

With coastal stations 300 to 500 miles apart, a 300-mile range for the ship set for coastal service should be sufficient in most cases. This means a 50-watt set with a reasonably good antenna. For short-range harbor service, lower powers such as 15 watts or less may be adequate, particularly in view of the possibility of remotely controlled receiving stations as will be explained later.

Fortunately, the space available varies roughly as the range requirements. That is, the vessels which travel the greater distances are usually the larger ones. Vessels requiring 50-watt sets therefore generally have a little more room available than do vessels which can get along with 15-watt sets. However, in any case, most of the vessels are small and space of any kind is usually at a premium. In general, therefore, the sets should be as small as possible and designed so that they may be mounted in out-of-the-way corners or lockers.

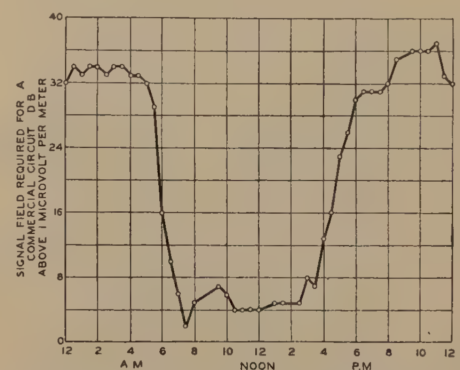


Fig. 5—Diurnal variation in noise in terms of signal field required for commercial circuit. Frequency, 2500 kilocycles, Forked River, N. J., October, 1931.

In order that the ship's personnel be able to operate the equipment, it must be simple to operate and be sufficiently reliable so as not to require any maintenance attention while the vessel is away from the home port, which may be several weeks. For the sake of simplicity, the operational controls consist generally of a switch for turning the equipment on or off, a volume control, a simple method for shifting frequencies when necessary, and a handset push button to be pressed when talking. In some cases this push button is unnecessary as speech itself is used to switch the antenna to the radio transmitter and to control the transmitting carrier. The transmitter is in operation only when the handset is removed from its cradle. In order to avoid the necessity for the ship's personnel to monitor the shore station continuously, selective signaling is available at most shore stations whereby the shore-station traffic operator can dial any individual vessel suitably equipped and ring a bell on the boat.

For coastwise vessels, it is necessary to change both transmitting and receiving frequencies as the vessel proceeds from the service area of one shore station to that of another. In general, this need not be a quick change. An additional frequency requirement for the boat sets involves the use of a frequency

for direct boat-to-boat calls, namely, 2738 kilocycles. Arrangements for such calls may be made through the shore station or direct between ships on a schedule basis. It should be possible to make a reasonably quick shift to the boat-to-boat frequency, preferably with automatic restoration to the shore-station frequency upon the completion of the call.

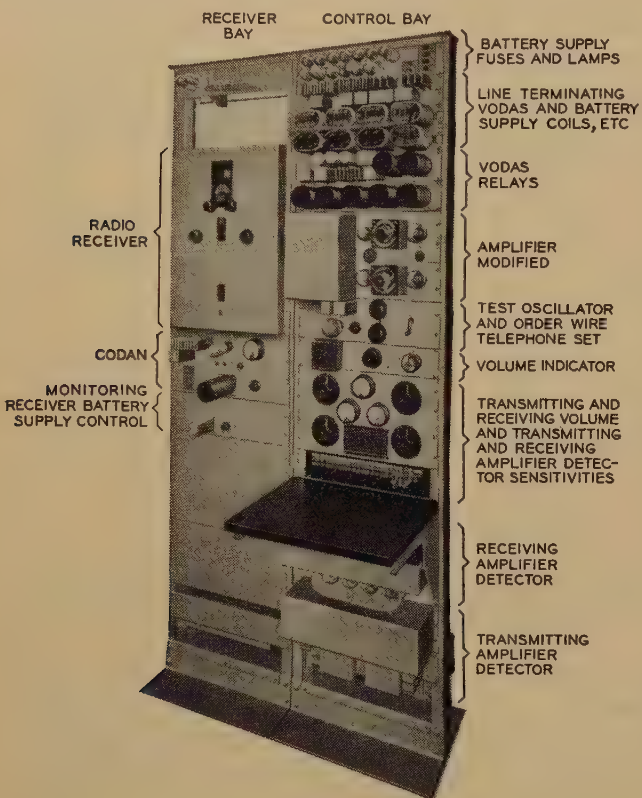


Fig. 6—Early design of radio receiver and control terminal for harbor radiotelephone station.

No provision need be made for the boats monitoring on a distress frequency. Arrangements are made at each shore station for distress calls to be routed directly to the local life-saving agency, usually the United States Coast Guard, and the system put at their disposal for the duration of the emergency.

Shore-Station Equipment Considerations

Prior to the consideration of radiotelephone service for small vessels, the shore radio system consisted of separate radio transmitting and receiving stations and a control terminal with personnel at all three points. It was apparent that the expense of three stations was too great to enable service to be given at a rate low enough to attract any business. One of the early requirements was, therefore, to combine the three units of the terminal with one attendant to make such receiver, transmitting volume, and sensitivity adjustments on each call as were necessary and to maintain the apparatus in good operating condition. The only other person required for the operation of the shore terminal was the traffic operator. Fig. 6 shows the technical operating position for such a terminal.

In order to simplify operation still further, the next step was to eliminate all manipulations of the receiver and the control terminal. Eliminating the receiver controls would permit the radio receiver to be located at some remote point and materially simplify the receiver location problem. Fortunately, the frequency from the boat transmitters to shore was fixed and usually crystal-controlled. The shore receivers could, therefore, also be crystal-controlled, thereby making any tuning adjustment unnecessary. Automatic-volume-control circuits had been developed to a point where volume adjustments were not required. In receivers equipped with automatic volume control, the receiver gain varies inversely as the strength of the signal. With no signal, as when the ship's transmitting carrier is off, the gain is maximum and noise is amplified accordingly. To prevent these bursts of noise from disturbing the shore subscriber or from falsely operating the switching relays, a relay operated from the automatic-volume-control circuit of the receiver was used to cut off the receiver output except when a transmitting carrier was present. This device is called a "codan" from the initial letters of the words "carrier-operated device anti-noise." The sensitivity of the device was adjusted just below the operating point on noise. If noise were constant throughout the day and seasons, one such adjustment would suffice. However, if the sensitivity is adjusted for high nighttime noise, and higher signal fields too, incidentally, the codan would not operate on the weak daytime fields although, because of the low daytime noise, these fields would be satisfactory for service. The design of an unattended receiver, particularly with regard to a codan which would not operate on noise with the receiver at full sensitivity, was one of the major problems of the development.

A receiver capable of unattended operation is also the solution to another problem, namely, the extension of the service area for low-powered ship sets. For example, in New York harbor, the service area from 15-watt boat sets with a single receiving site, Staten Island, extends from below about 60th Street in the Hudson and East rivers to, say, Sandy Hook. The shore transmitting range is, however, considerably greater. With receivers at Perth Amboy, Whitestone Point, and near Port Jefferson, the service range of a 15-watt set has been increased to include not only New York Harbor, but nearly all of Long Island Sound as well. Putting it another way, the

use of three additional shore receiving stations has meant a material increase in the number of potential users of the service as a low-powered set will now be adequate for many boat owners who could not afford the higher-powered and more expensive boat sets.

With the necessity of shore-station receiver adjustments eliminated, the only other technical operating control of importance is the control of the speech volume from the shore subscriber. Various talkers and various land lines result in a wide variation in speech volumes delivered to the control terminal. These volumes must all be adjusted to modulate the radio transmitter adequately and avoid overloading with its accompanying spurious radiation. A device which would compensate for these variations in speech volume would relieve the technical operator of a tedious job and permit him to attend to his other duties without interruption at each call. Such a device is the vogad, voice-operated gain-adjusting device.

With routine operation of controls by a technical attendant unnecessary, with means provided for selectively signaling a particular boat or group of boats, with automatic switching controls, alarms, and signals, the system has gradually been taking on more and more the aspects of the wire telephone system.

Radio Transmitting Station

The shore radio transmitting station consists of the radio transmitter, rectifier, antenna radiating system, transmitting-line amplifier, and miscellaneous control equipment. In some cases a gas-engine-driven alternator is used for emergency power supply.

The transmitter is a 400-watt Western Electric No. 9C radio transmitter. A photograph of this transmitter together with its associated rectifier and antenna tuning unit as installed at New York is shown in Fig. 7.

Either a current-fed or a voltage-fed antenna[3] may be used. A current-fed antenna may consist of a 60- to 100-foot vertical conductor with or without a horizontal top, suspended from one or more poles or towers. An antenna tuning unit is used for coupling the 500-ohm transmitter output to the low-impedance antenna. Buried ground systems may or may not be used depending on soil conditions. Often the stations are located on a salt-water marsh or so close to sea water that an extensive ground system is not essential. Our experience with voltage-fed antennas for this frequency range is limited to the installation at Norfolk. A standard steel 80-foot flagpole is fed by means of a single-wire transmission line connected to the pole about 20 feet above the ground. Such an antenna is particularly suitable from the appearance standpoint when it is desired to locate the transmitting station in a residential section.

The transmitter can be turned on or off either locally or remotely. Provision is also made for permitting the transmitter to operate in a "stand-by" condition with reduced filament current and no plate voltage. This permits the transmitter to be operated with full power without the 30-second delay involved in starting from the completely "off" condition.

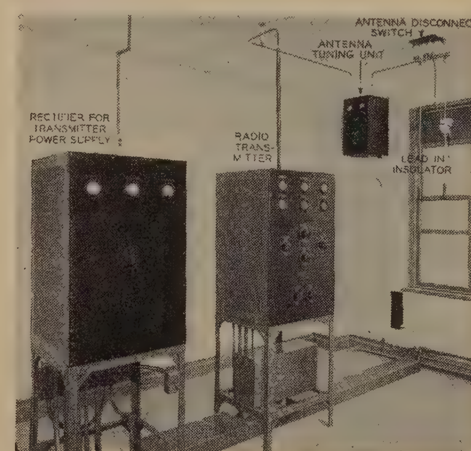


Fig. 7—Radiotelephone transmitting station for harbor and coastal service.

Radio Receiving Station

The radio receiving station in its simplest form consists simply of a radio receiver and antenna with telephone and power connections. An emergency power supply and a test oscillator may be added.

The fact that the radio receiver may be operated unattended permits the entire equipment to be placed in a housing and mounted on a pole as is shown in Fig. 8. This not only reduces the expense of the receiving site and building but also simplifies the problem of locating receivers at advantageous points.

The receiver is a Western Electric No. 23A radio receiver and has been described elsewhere.[4] It may be operated on either alternating- or direct-current supplies and its outstanding feature is the codan which does not operate on noise and permits the receiver to be operated over a wide range of noise conditions without readjustment.

The test oscillator, mounted above the receiver, is crystal-controlled at the frequency of the incoming carrier. The output may be modulated with 1000

[3] J. F. Morrison and P. H. Smith, "The Shunt-Excited Antenna," Proc. I.R.E., vol. 25, pp. 673–696; June, (1937).

[4] H. B. Fischer, "Remotely controlled receiver for radiotelephone systems," Proc. I.R.E., this issue, pp. 264–269.

cycles. The purpose of this oscillator is threefold; namely, (a) for testing whether the receiver is operating properly (output, tone-modulated); (b) for testing the frequency deviation of the incoming signal (unmodulated output), and (c) for signaling back to the control point when emergency power is being used and when regular power is restored (tone-modulated output).

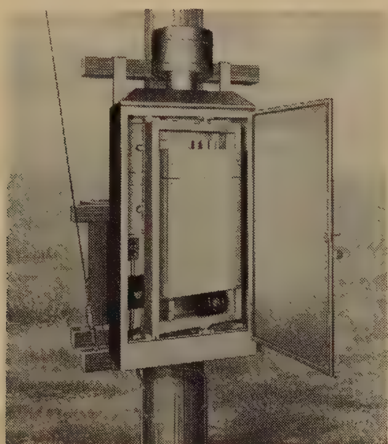


Fig. 8—Unattended radiotelephone receiving station for harbor and coastal service.

The emergency power supply consists of a 120-ampere-hour storage battery, kept charged by a trickle charger, which supplies filament currents and operates a dynamotor for the 200-volt plate supply. This supply can handle the load for about eight hours.

Control Terminal

The control terminal of a radiotelephone system connects the two-wire line from the switchboard to the circuits associated with the input of the transmitter and output of the receiver.

This terminal performs the following functions:

1. Prevents reradiation of received speech and noise on normal calls.
2. Regulates volume of transmitted speech to obtain full modulation of the transmitter.
3. Provides for selective calling of ships.
4. Signals traffic operator for incoming calls from ships.
5. Provides for turning the transmitter on or off.
6. Provides for turning on the receiver test oscillator, either for testing receiver operation or ship transmitting frequency.
7. Provides transmitter power alarms and monitoring means for determining transmitter frequency and approximate modulation and radiation.
8. Provides for connecting the receiving and transmitting circuits together to permit the shore station to act as a repeater for ship-to-ship calls using the ship-shore frequencies.

In its simplest form the control terminal might consist of a hybrid coil for combining the transmission circuits and limiting reradiation of received voice currents. In practice, however, such a control terminal would be unsatisfactory because it would not permit adjustment of the transmitting gain over a sufficient range without causing excessive reradiation of received speech and noise.

The earlier type of harbor telephone terminal employs the circuit arrangement shown in Fig. 9. This terminal is shown in the photograph Fig. 6 and employs a somewhat simplified version of the voice-operated device used on the long transoceanic circuits.[5] This type of terminal requires the constant attention of a technical operator during calls to operate the controls. Since the most important control is that for maintaining transmitting volume, schemes for using automatic devices have been considered for use with this type of terminal, but the problem has been somewhat complicated by the necessity for making an opposite adjustment of the receiving volume control when the local subscriber's voice is weak or the radio noise is high.

Recent improvements in the codan, a carrier-operated device, have enabled us to design an entirely new type of control terminal. The circuit schematic of this new type of terminal is shown in Fig. 10. In designing this terminal, it was assumed that practically all ships will use controlled-carrier

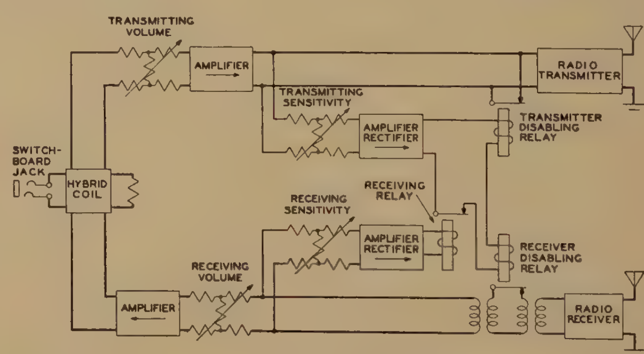


Fig. 9—Schematic of early type of control terminal, voice-control switching, manual volume and sensitivity adjustments.

systems that radiate carrier only while talking. This terminal is intended to operate without manipulation of controls during each call. It consists mainly of a switching relay and a voice-operated gain-adjusting device called a vogad. The subscriber is normally connected through the gain-adjusting device to the

[5] S. B. Wright, "The vodas," *Elec. Eng.*, vol. 56, pp. 1012–1017; August, (1937); and *Bell Sys. Tech. Jour.*, vol. 16, pp. 456–474; October, (1937).

input of the radio transmitter. The switching relay, controlled by means of a simplex circuit from the codan in the radio receiver, transfers the subscriber to the receiving circuit whenever the ship subscriber speaks. There is no direct relation between the permissible transmission gains or losses on the two sides of the circuit so that the requirements for the vogad or voice-operated gain-adjusting device are somewhat simpler than for the earlier type of terminal.

The vogad[6] operates to maintain a fairly constant output volume over a wide range of input volumes. It will handle input volumes between +10 and −35 decibels to give a nearly constant output of 2 decibels above reference speech volume.

The traffic operator must be provided with means for selecting any one of a number of radio receivers. This is done by providing a separate switchboard jack for each of the receivers, each jack operating a connecting relay to associate a receiver and its direct-current control circuit with the switching relay.

The plate and filament powers of the radio transmitter can be controlled separately by relays operated by direct current over the conductors of the transmission circuit. These control circuits are operated either manually by keys on the control terminal or automatically through the connecting relay as the traffic operator makes connection to any of the switchboard jacks.

The controls required between the radio receiver and the control terminal are the control of the

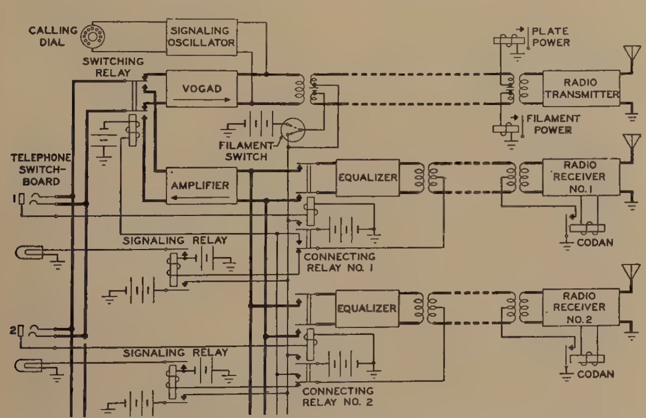


Fig. 10—Schematic of later type of control terminal, carrier-control switching, automatic control of speech volume.

switching relay by the receiver codan, the control of the two test oscillators, and the control of the relays associated with the emergency power alarm. All these controls are accomplished by an arrangement of polar relays. The codan relay in the receiver operates the switching relay in the terminal by sending direct current over both conductors of the transmission circuit in the same direction. Relays in the receiver for controlling testing oscillators are controlled by making currents flow over the conductors in opposite directions. Relays associated with the emergency power alarm are controlled by operating and releasing the oscillator relays in certain sequences.

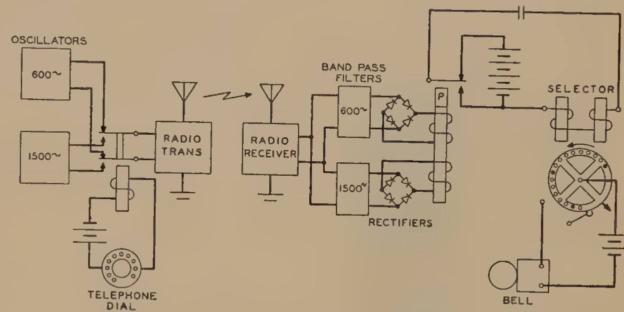


Fig. 11—Schematic of selective signaling system.

Signaling from ships to the shore station is accomplished through the carrier-operated devices in the radio receivers. A ship station calls the shore by radiating carrier current. The carrier current from the ship's transmitter operates the codan in the receiver to pass a signal over the simplex circuit to the control terminal. When the control terminal is idle the circuits are arranged so that these signals operate relays to light lamps at the switchboard and turn on the local transmitter. The operator extinguishes the switchboard lamps by answering the call.

Signaling from the shore to the ships is provided by means of a selective signaling system operated on signals radiated from the shore transmitter. Fig. 11 shows the operating plan of this system. On the shore two oscillators are provided, one delivering 600-cycle current and the other 1500-cycle current. A telephone dial is arranged to connect these oscillators alternately to the transmitting circuit in accordance with preassigned codes. For each impulse from the dial, a single change in tone is produced.

On each ship the radio receiver is connected to the input of two band filters. The outputs of the two band filters are connected through rectifiers to opposing windings on a polar relay. This arrangement of band filters and balanced relay windings makes the device comparatively insensitive to radio noise since most types of radio noise produce approximately equal currents in the two relay windings. The contacts of the relay are connected to a condenser, the windings of a selector, and a source of direct current. When a signaling tone is received the polar relay closes one of its contacts and each change in frequency of the incoming audio-frequency signal moves

[6] S. B. Wright, S. Doba, and A. C. Dickieson, "A vogad for radiotelephone service," Proc. I.R.E., this issue, pp. 254–257.

the armature from one contact to the other. The condenser in series with the selector winding is charged or discharged on alternate dial pulses. Each charge or discharge of the condenser through its windings causes a code wheel in the selector to advance one step. A series of holes located around the circumference of the code wheel have pins inserted in accordance with the particular code number for each particular selector. If the successive groups of impulses correspond to the pin locations, the code wheel

Fig. 12—New type of control terminal for harbor and coastal radiotelephone service.

will be held at the end of each group and eventually stepped up to the last pin, which closes the local bell circuit. The code wheel will drop back to its initial position at the end of a code group if a pin is not located in the hole corresponding to the code group dialed. One pulse will return the code wheel to its initial position from any pin.

One feature of the terminal not shown is the use of the shore station as a repeater for handling calls between ships. This is done by substituting a resistance network for the switching relay. A second jack at the switchboard for each radio receiver operates the connecting relays in the usual manner and also operates a relay to make this substitution. When the resistance network is used, received speech is reradiated, and the transmission circuit still appears at the switchboard.

Keys are provided on the terminal so that a technical operator can perform manually any of the functions controlled from the switchboard, such as operate the receiver connecting relays, turn on the transmitter, and operate the selective signaling system. In addition to these functions, the technical operator can monitor on the radio circuit and control the receiver test oscillators.

A photograph of this terminal is shown in Fig. 12.

Traffic Switchboard

The equipment at the switchboard for the radio circuit consists of two jacks, a line lamp, and a busy signal for each reciever, a lamp, a key, and a dial for signaling.

The transmission circuit is multiplied to all of the jacks, which differ only in the control functions they perform when connection is made to them. The two jacks associated with each receiver are called line and by-pass jacks. The line jacks are used for handling all calls between the shore and ships with controlled carrier. The by-pass jacks are used for handling calls between two ships and between the shore and ships radiating continuous carrier.

System Operation

The operation of the system can be summarized by referring to Fig. 10 and following the sequence of the operations involved in setting up a circuit from and to a ship.

When a circuit is set up from a ship the handset is removed from its hanger and the ship transmitter is put in operation. The ship's transmitting carrier operates the codan circuit on one or more of the shore receivers. This places ground on the codan control circuit to operate the signaling relay and light the associated lamps on the switchboard. The signaling relay also connects the battery to the transmitter control circuit and puts the transmitter in operation. A switchboard cord circuit is then connected to the line jack associated with a lighted signal lamp. This connects battery to the sleeve of the jack, energizing the associated connecting relay to keep the transmitter in operation and to connect the desired receiver to the receiving amplifier. During the conversation the codan circuit operates the switching relay.

In setting up a circuit to a ship, the dial key is operated to connect the signaling oscillator to the transmitting circuit and to start the radio transmitter. As soon as the carrier from the transmitter is received on the monitoring receiver at the terminal, a lamp is lighted at the traffic position. The ship's assigned code is then dialed which results in the ringing of the bell on that particular ship. When the ship answers, the carrier from the ship transmitter operates the codan of the shore receiver and a signal lamp on the switchboard is lighted. The dial key is then released

and a cord circuit connected to the proper jack. The procedure is then the same as previously explained for setting up a call from the ship.

When the shore station is communicating with a ship not equipped for carrier control, the "by-pass" jack instead of the line jack must be used to prevent the ship's carrier holding the switching relay in the receiving position. On such calls, received speech is reradiated by the transmitter.

When a circuit is set up between ships, the calling ship must ask the shore switchboard to dial the other ship. A cord must be left connected to a by-pass jack to keep the transmitter in operation and keep a receiver connected to the transmitter.

If the two ships are not within range of the same receiver, a cord must be kept in each of the by-pass jacks to keep the two receivers in operation.

Additional Bibliography

R. S. Bair, "Ship equipment for harbor and coastal service," Proc. I.R.E., this issue, pp. 258–263.

E. B. Hansen, "Ship-to-shore radio in Puget Sound area," *Elec. Eng.*, vol. 54, pp. 828–831; August, (1935).

F. A. Gifford and R. B. Meader, "Marine Radiotelephone service," *Com. and Broad. Eng.*, vol. 2, pp. 9–11, 15; October, (1935); digest in *Bell Sys. Tech. Jour.*, vol. 14, pp. 702–707; October, (1935).

W. M. Swingle and Austin Bailey, "Coastal and harbor ship radiotelephone service from Norfolk, Virginia," Proc. I.R.E., this issue, pp. 270–276.

A Vogad for Radiotelephone Circuits*

S. B. WRIGHT,† ASSOCIATE MEMBER, I.R.E., S. DOBA,† NONMEMBER, I.R.E., AND A. C. DICKIESON†, NONMEMBER, I.R.E.

Summary—*Commercial radiotelephone connections must generally be accessible to any telephone in an extensive wire system. Speech signals delivered to the radio terminals for transmission to distant points vary widely in amplitude due to the characteristics of the wire circuits and individual voices. To provide the best margin against atmospheric noise, it is usually the practice to equalize this wide range of speech amplitudes and thus drive the radiotelephone transmitter at its full capacity.*

Many devices have been proposed to adjust automatically the gain in a circuit to equalize speech volumes. The difficulties of providing a device which will respond properly over a wide range to the complex qualities of a speech signal have only recently been overcome to a satisfactory degree.

The voice-operated gain-adjusting device, or "vogad," described in this paper is a practical design based upon more than a year's experience with one of the most promising devices made available by earlier development effort. A trial installation of this latest vogad is now under way at Norfolk in connection with a new radiotelephone system for harbor and coastal service.

In commercial radiotelephone connections, atmospheric noise often limits transmission. Since radio transmitter power capacity is relatively large and expensive, it is generally economical to control the speech signals so that the transmitter will be fully loaded whether the talker's voice waves are strong or weak. Thus the effect of the noise is held to a minimum for a given transmitter power rating.

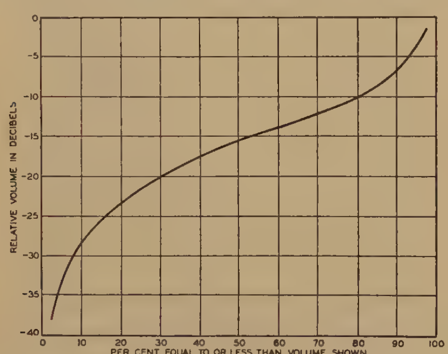


Fig. 1—Distribution of input volumes.

The vogad is a device that transforms varying input speech volumes[1] into an essentially constant output that will load the radio transmitter to its maximum efficiency, without overloading on peaks. This action it performs automatically, improving the performance of unattended radio systems and removing an irksome, routine manual adjustment from attended systems. The word "vogad" is formed from the initial letters of the words "voice-operated gain-adjusting device."

Volumes Supplied by Telephone Conversations

The sound energy that the telephone transmits consists of complicated waves made up of tones of different pitch and amplitude. The local lines and trunks connecting telephone subscribers to the toll switchboard have little effect in changing the fundamental characteristics of these waves. However, because of wire-line losses, the waves received at the toll switchboard are always weaker than those transmitted by the telephone. Furthermore, their strength varies with the method of using the telephone, loudness of talking, battery supply, and transmitter efficiency. The subscriber may be talking over a long-distance circuit from a distant city, in which case any net loss in the toll connection further attenuates the waves. Fig. 1 shows that the spread of speech volumes as measured at the transmitting toll switchboard by a volume indicator is nearly 10,000:1 in power ratio (40 decibels) for talkers connected to the circuit by a local-exchange plant in the same area. Similar data indicate that when calls are made from distant points the range is about the same but the average volume is even lower. Furthermore, the curve in Fig. 1 gives only one reading for each call which corresponds to the average volume for that call. Data on a limited number of such calls indicate that variations in volume during a call which amount to 5 decibels higher than average and 10 decibels lower than average are not uncommon.

Function of a Vogad

In the vogad the functions of manual control of amplification with the aid of a volume indicator have been followed as closely as an electrical substitute for manual operation would allow. Thus, when speech is present, the vogad rarely assumes either a maximum or a minimum gain but takes the value required to give the correct output. Also, when no speech is applied to the vogad it does not adjust but remains at the gain existing when the speech ceases. In addition, while a subscriber at the distant end of the circuit is talking, the gain remains where it was set by the last outgoing speech. The time actions are so designed that the vogad does most of its adjusting on the strong parts of speech corresponding to the maximum deflections of the volume indicator. Frequency discrimination is included in its control circuit to assist

* Decimal classification: R412. Original manuscript received by the Institute, May 21, 1938. Presented before I.R.E. Convention, New York, N. Y., June 18, 1938.

† Bell Telephone Laboratories, Inc., New York, N. Y.

[1] Volume is that measure of the intensity of electrical speech waves that is read on instruments called "volume indicators."

it in distinguishing between fluctuations which are speech and those which might be due to noise.

Thus, it is evident that the problem of designing a vogad is inherently more difficult than that of more familiar types of gain control, such as those operated by a single pilot frequency (carrier automatic volume control) and devices which limit overloading through a relatively small range.

Functional Parts

The various functional parts of the device dealt with in this paper are outlined below and compared with the corresponding functions in manual operation.

1. Variorepeater. A variable-gain device, the gain of which is adjusted by the several control circuits. Corresponds to the technical operator's gain-control knob.
2. Integrator. This circuit weighs and sums the impulses from the control circuits, determining how much and in what direction gain is to be changed. Corresponds to the operator's judgment in changing the setting of the gain-control knob.
3. Gain increaser. This circuit responds to input signals above a given threshold which is determined by the requirement that the device should not operate on noise from telephone circuits. Since the peaks of the weakest talkers are usually well above this limit, the gain increaser tends to increase the variorepeater gain whenever speech is present. Corresponds to the operator's judgment in differentiating between speech and noise.
4. Gain-increase disabler. This responds to output voltages above a given value to prevent the gain increaser from operating.
5. Gain decreaser. This circuit operates so as to reduce the gain whenever the output exceeds a critical value. The actions of these last two circuits correspond to the visual response of the operator to the volume-indicator reading.

Steps in Development

In the development of a successful vogad several problems had to be solved. The first of these was a suitable variorepeater. In early development an attempt was made to use mechanical devices for controlling the gain. Two types of these mechanical vogads were set up, the first using relays to insert various values of loss, and the second using a motor-driven potentiometer.

The relay type of vogad consisted of a group of amplifier detectors operating a bank of relays. The operation was essentially that of inserting fixed amounts of loss if given values of input voltage were exceeded. This vogad was the first successful one built, but was not entirely satisfactory due to the abruptness with which the losses were inserted and the finite stepping of loss which made small steps cumbersome and expensive.

The second type of vogad constructed utilized a motor-driven potentiometer as the variable-gain element, and had control circuits similar to present vogads. Although the problems due to the previous circuits were overcome, other difficulties were introduced. These included the slowness of operation of the potentiometer and troubles in the sliding contact.

The next vogads in the line of development used vacuum tubes for the variorepeaters with mechanical relays used only in some of the control circuits. The variorepeater consisted of a push-pull stage of 3-element low-μ vacuum tubes in which the gain was controlled by means of a varying grid bias. This bias was furnished by the charge on a condenser circuit of sufficiently high insulation resistance so that the charge and hence the gain could be held constant over comparatively long times when no change was required.

The gain increaser consisted of an amplifier-detector operating a relay which connected a low-resistance shunt across the gain-control condenser. The gain-increase disabler consisted of an amplifier-detector operating another relay which interrupted the discharge path provided by the gain increaser. The gain decreaser consisted of a biased rectifier which charged the control condenser to reduce the gain.

The disadvantages of this circuit may be summed up as follows. Because of the availability of 3-element tubes only, the input voltage to the variorepeater and hence the range controlled with a single stage was limited. The use of mechanical relays in the leakage path of the gain-control condenser made quite difficult the maintenance of the necessary high-insulation resistances to ground.

Design of Present Vogad

In the latest type of vogad, Fig. 2, the use of modern variable-μ tubes in combination with copper-oxide varistors for the variorepeater has expanded the permissible input-voltage range so that a wider range of input volumes can be controlled with an economy of vacuum tubes. The use of argon-filled cold-cathode tubes in place of mechanical relays has also helped improve the device in reducing maintenance and in eliminating leakage paths.

Variorepeater

The variorepeater includes a one-stage push-pull amplifier using variable-μ pentode tubes, whose grid bias is supplied by the integrator, and whose gain and

cathode current both are reduced as grid bias is made more negative. Supplementing this is a copper-oxide varistor circuit, whose loss depends on the cathode current of the variable-gain stage. The circuit is arranged so that high cathode current causes a biasing voltage to be applied to the varistor in the nonconducting direction. As the cathode current approaches zero, the bias on the varistor is set by a voltage divider across a 24-volt battery and is in the conducting direction. In this way, the impedance of the varistor bridged across the transmission circuit follows the cathode current, extending the range of gain change, and affecting the sensitivity of the gain increaser as described below.

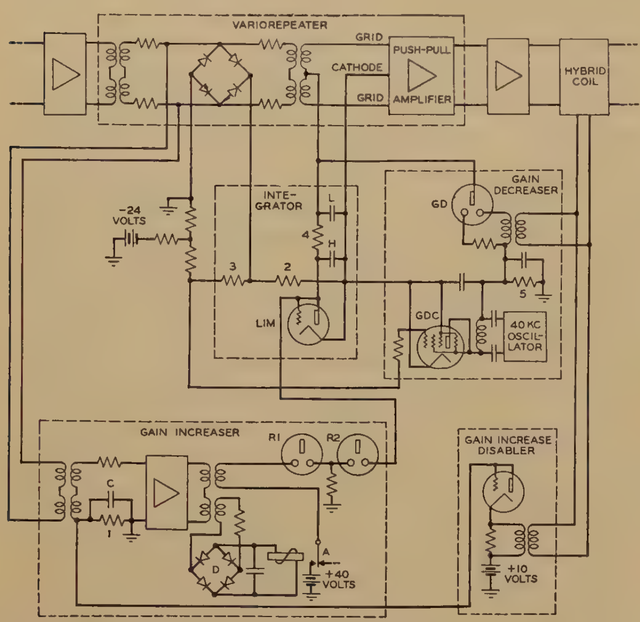


Fig. 2—Simplified schematic diagram of a vogad.

The fixed-gain amplifiers before and after the variorepeater are used to fit the range of input volumes to the working range of the variable portion, and to set the output to the value desired for the radio transmitter.

Gain Increaser

The gain increaser comprises a two-stage amplifier tuned to near the middle of the voice-frequency band, acting through two cold-cathode gas tubes to charge the integrator circuit positive with respect to ground. When speech of sufficient amplitude is present, part is rectified by the copper-oxide unit (*D*), and operates relay (*A*). This closes the circuit through gas tube (*R*1) and a 40-volt aiding bias. When the sum of the alternating-current potential and the 40-volt bias exceeds about 70 volts, gas tube (*R*1) becomes conducting, producing a voltage applied to gas tube (*R*2). When this voltage rises above about 70 volts, gas tube (*R*2) breaks down, and current charges the integrator in the positive direction, thus raising the gain of the variorepeater.

When a high volume is applied to the input, the gain increaser tends to operate a greater proportion of the time than for a low volume. This would tend to give a higher output for a high-input volume than for a low input. To counteract this condition, the gain increaser is connected across the bridged varistor in the variorepeater circuit. As a result, when the gain of the variorepeater is high (low input volume), the loss through the varistor is low, and the impedance across which the gain increaser is connected is high. Consequently, a given input power is more effective in operating the gain increaser when the variorepeater gain is high (low volume) than when it is low (high volume).

Relay (*A*) is made rather slow operating, so that a click or brief spurt of noise either does not operate it or else causes a momentary closure of the contacts after the click has passed on. This prevents operation of the gas tubes, which would cause a false gain setting. Relatively sustained speech currents, however, operate the relay after a delay of about the length of a short syllable, which does not materially affect the gain-increase action.

Gain-Increase Disabler

The gain-increase disabler is a rectifier connected to the output of the variorepeater. When speech exceeding a certain amplitude is present, part is rectified and the resultant negative bias is applied to the grid of the first amplifier tube of the gain increaser. This desensitizes and for sufficient inputs disables it, and because of the slow discharge rate of condenser (*C*) and resistance (1), no subsequent gain increase is possible for a period of about one-half second.

Gain Decreaser

The gain decreaser is a cold-cathode gas-tube rectifier connected at the same point as the gain-increase disabler but somewhat less sensitive. When the speech amplitude exceeds a predetermined value, current flows through gas tube (*GD*), charging the integrator in the negative direction to reduce the gain of the variorepeater. It is desired that the amount of decrease in gain caused by a particular speech output voltage should be independent of the previous gain of the variorepeater. However, since the voltage due to the charge already stored in the integrator opposes the voltage from the gain decreaser, the decrease in charge caused by a given small increase in output is

smaller for low gains than for high gains. In addition the relationship of gain versus grid bias for the variorepeater is curved so that the decrease of gain caused by a given increase in negative grid voltage is smaller for low gains than for high gains. Because of these two effects, it is necessary to make a given small increase in output relatively more effective in decreasing the gain as the gain becomes smaller. The process of shaping the characteristic to produce these changes is carried out by tube (*GDC*). Its plate current flows through resistance (5) determining the direct-current bias on gas tube (*GD*). The grid potential of tube (*GDC*) is the drop across resistances (2) and (3), caused by the plate current of the variorepeater stage. When the gain is high, the negative grid potential on tube (*GDC*) is high, and the aiding direct-current biasing voltage on gas tube (*GD*) is low. Therefore, the amount by which the charge on the condenser is reduced by a given increase in output voltage is less for this condition than for the condition when variorepeater gain is low. The 40-kilocycle oscillator is used only as a source of ungrounded potential that would otherwise have to be supplied by an ungrounded dry-cell battery or other means.

Integrator

The integrator comprises the two condensers (*L*) and (*H*), the resistance (4) and the limiter tube (*LIM*). Condenser (*L*) is about 1/10 the capacitance of (*H*), and is separated from it to a certain extent by resistance (4). The gain decreaser is connected to (*L*), so that if a speech peak operates the (*GD*) tube, condenser (*L*) charges rapidly reducing the gain and limiting the output peak. If the peak is of short duration, the total charge stored in the integrator will be small, and subsequently condenser (*L*) will discharge into condenser (*H*). By this means, peak limiting can be made fast acting, without giving undue weight to a short peak in setting the gain. This is an action whose rapidity cannot be matched manually.

The limiter tube is used to prevent the grid bias of the variorepeater tubes from becoming very positive which would cause excessive gain reduction, and disrupt the control functions.

Conclusions

As shown on Fig. 3, the vogad automatically reduces an applied volume range of about 40 decibels to a range in which 90 per cent of the outputs are within ± 3 decibels as read on a volume indicator. It also operates on high peaks of short duration to prevent overloading of the radio transmitter. The transmission-frequency characteristic is flat within ± 1 decibel from 200 to 6000 cycles at all gains. All unwanted modulation products are at least 30 decibels down from wanted components, except while it is operating to reduce gain on high inputs, which occurs for short and relatively infrequent periods.

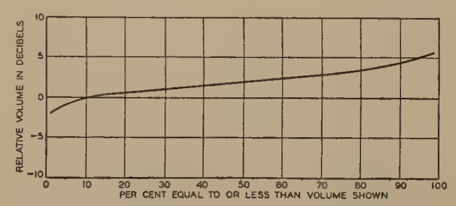


Fig. 3—Distribution of output volumes.

Acknowledgment

The accomplishments dealt with in this paper are due to the concerted efforts of a large number of workers in the Bell System. Particular thanks are due to the operating personnel of the transatlantic radiotelephone control terminals in New York.

Added in Proof: Since this paper was prepared, vogads have been placed in commercial service in a similar system at Miami, Florida, and in the transatlantic radiotelephone service at New York, N. Y.

Ship Equipment for Harbor and Coastal Radiotelephone Service*

R. S. BAIR†, MEMBER, I.R.E.

Summary—*The ultimate objective in the design of radiotelephone apparatus for use on ships is to provide equipment which is as convenient and simple to operate as the telephone at home. To a considerable degree this has been accomplished in the new 15- and 50-watt ship sets that have recently been designed for use on harbor craft and coastwise vessels.*

The requirements for sets of this type are discussed and the new equipment is described in this paper.

WHEN radiotelephone service was first inaugurated for the benefit of harbor craft, yachts, and commercial vessels operating in coastal waters, the boat equipments used were composed largely of apparatus developed for aviation and other mobile applications. On the whole, these equipments have performed satisfactorily and have served to demonstrate the practicability of a marine telephone service for these smaller boats. Installations on a wide range of sizes and types of boats have, however, clearly indicated a number of desirable changes in the equipment to simplify the installation and operation, to provide increased reliability, and to reduce greatly the cost of maintenance and operation.

It is the purpose of this paper to discuss the apparatus requirements found desirable for different types of boat installations and to describe two marine radio equipments especially designed for this service.

The ideal equipment would be one which would function like the ordinary house telephone with a bell for calling and nothing but a handset to be concerned with while conversing. However, the radio equipment requires a source of power to operate it, an antenna, and reasonable installation conditions. For boats wishing telephone service through more than one harbor station or wishing to talk directly to other boats, it is also necessary to have controls for selecting the corresponding frequency channels. These factors must be carefully considered in determining the apparatus requirements for different applications.

Provision for this service on a two-frequency basis has been made by reserving frequencies between 2100 and 2200 kilocycles for transmission from boats and between 2500 and 2600 kilocycles for transmission from harbor stations. A pair of frequencies is assigned for use at each shore station. Other frequency assignments that may be used by these boats are the boat-to-boat frequency (2738 kilocycles) and the Coast Guard emergency frequency (2670 kilocycles). Boat equipments should, therefore, be capable of transmitting on frequencies from 2100 to 2800 kilocycles and receiving on frequencies from 2500 to 2800 kilocycles.

For boats operating entirely in one harbor a single pair of frequencies is all that is required but such boats will usually wish to be able to talk on the boat-to-boat channel and may wish also to call the Coast Guard in emergencies. Equipment for this service should therefore be arranged for operation on at least three and perhaps four channels in order that such boats plying between two adjacent harbors such as New York and Boston may be able to operate in either harbor. Coastwise vessels require separate frequencies for each harbor station they pass in the course of their travels. The engineering plan of the Federal Communications Commission makes provision for nine frequencies for radiotelephone communication with shore stations from boats in coastal waters. This is, of course, exclusive of the Great Lakes. A single ship would seldom have need for all of these and therefore eight channels in addition to the boat-to-boat channel and the Coast Guard channel are made available in the equipment under discussion.

In the interest of reliable telephone communication and simplicity of operation both transmitter and receiver should have crystal frequency control. Accurate frequency control of the transmitter is necessary to insure proper reception at the harbor station and it is also required by government regulation to prevent interference to other services. In order to be sure of receiving incoming calls the ship's receiver must be accurately tuned to the desired shore-station frequency while that station is inoperative. The use of a superheterodyne receiver with a crystal-controlled oscillator is the only satisfactory solution that has been found for this type of operation. Crystal control is particularly necessary where selective signaling is employed.

Experience with the early equipments, together with a considerable amount of data collected from transmission characteristics in various harbors, has indicated that 15 watts of carrier power supplied to an antenna which may be erected on the ordinary small harbor craft such as tugs and motor launches should give adequate coverage for local service in a

* Decimal classification: R510. Original manuscript received by the Institute June 22, 1938. Presented before I.R.E. Convention, New York, N. Y., June 18, 1938.
† Bell Telephone Laboratories, Inc., New York, N. Y.

harbor. Large yachts and commercial coastwise vessels operating at much greater distances naturally require more power for adequate coverage. With the larger antennas possible on these boats satisfactory coverage should be provided with 50 watts of carrier power.

The receiver required for coastwise ships should be sensitive enough to make circuit noise the limiting condition of operation and selective enough to avoid interference from other marine and coastal radio services. It must also have a good automatic gain control in order to simplify the control of the equipment and to avoid missing calls as the boat moves away from the shore station. For harbor boats the requirements can be somewhat lower because of the increased signal levels encountered. Characteristics believed to be satisfactory for these services are presented later for the equipment under discussion.

Selective signaling has been in use on boats for several years and has been found very desirable. It provides a positive means of receiving calls without any of the discomfort of listening to all of the transmissions from the shore station.

Because of the great variety of sizes and models of boats using these equipments, the antennas must vary widely in size and efficiency and a single antenna must be used in most cases for transmission and reception. These factors make it necessary to provide flexible antenna tuning adjustments and to arrange for switching the antenna between transmitter and receiver during the course of a conversation.

The change from send to receive is sometimes accomplished by a switch on the transmitter which is operated by the person using the equipment. Operating the circuit in this way is usually very unsatisfactory because it requires the use of both hands, one to hold the handset while the other operates the switch, and it also requires the presence of the operator directly at the transmitter.

A better arrangement which has been in use for several years is to control the circuit by means of a push button in the handset which operates relays to perform the functions of the send-receive switch. This is a simple operation to perform with the hand that holds the handset and permits of considerable freedom on the part of the operator. This method of switching has been found quite satisfactory on small boats where only a few people operate the equipment. However, when the service is used by a large number of people at irregular intervals the use of the push button is found irksome and frequently results in unsatisfactory operation.

For the larger boats and yachts, therefore, it is preferable to perform this switching operation by means of relays operated by speech currents. In this way the telephone conversation may be carried on much as it is with a standard telephone.

The only other controls required for the equipment are switches to connect the power supply and channel or station selectors. The solution adopted for each type of equipment will be fully described later.

The primary power on boats which may be expected to use this radiotelephone equipment is obtained from steam, Diesel, and gasoline engines. In general, the electrical power which supplies the radio equipment is obtained from batteries charged by auxiliary engine-generator sets. 120-volt direct-current supply is usually available on boats 75 feet in length or greater, while smaller boats usually have either 32- or 12-volt supplies. It is obviously impracticable to manufacture, install, and service different equipments for each supply voltage. Fortunately, a variety of standard motor-alternators producing 120 volts alternating current are available to operate from each of these direct voltages. By using these machines the radio equipment can be uniform for all applications in the same class of service and the proper alternating and direct voltages for the various transmitter, receiver, and control-circuit

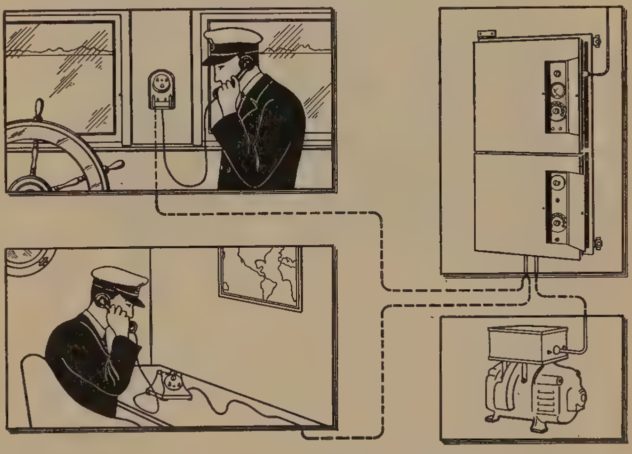


Fig. 1—50-watt marine radiotelephone equipment No. 224A.

functions may readily be obtained by the use of transformers and rectifiers. For most marine applications the power supply must be used as economically as possible because the electrical supply on small boats is usually very limited. This consideration is especially important in the low-powered set for small harbor craft and for the "stand-by" condition of both sets where the receiver will be operated continuously.

Other important considerations are the installation and maintenance of the equipment. Space is always at a premium on board ship especially on the smaller yachts and harbor craft. Fortunately, adequate serv-

ice for these boats is provided by a low-powered set which can be constructed in a single small unit. In this service the equipment will ordinarily be operated in the pilothouse where a limited amount of bulkhead mounting space is usually available within reach of the pilot. In some cases it may be necessary to extend the handset control for the convenience of the pilot. The high-power equipment for larger yachts and coastwise vessels is considerably larger and cannot ordinarily be installed at a desirable operating position. It must, therefore, be arranged for use with a remote-control unit, the main unit of the equipment being installed against a companionway bulkhead, in a closet, or under a bunk or seat. More than one remote-control position will frequently be required and should be provided for.

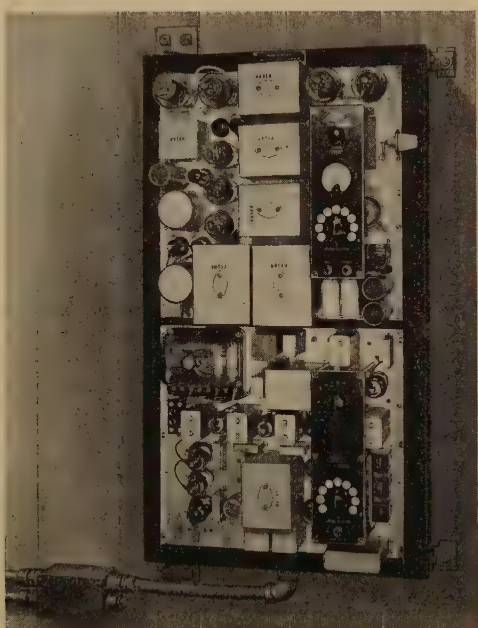


Fig. 2—50-watt set with front covers removed.

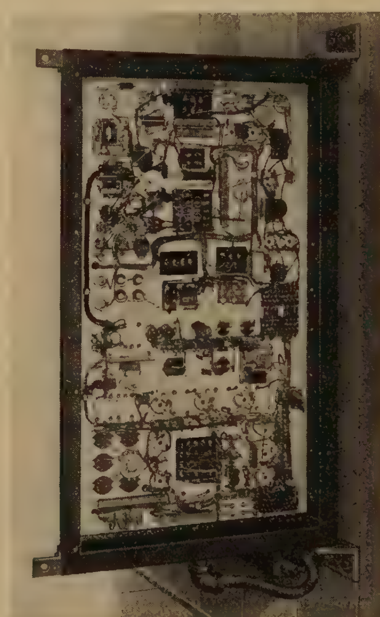


Fig. 3—Rear view of 50-watt set with cover removed.

Both equipments should be designed for ready accessibility from the front in order that they may be installed flat against a bulkhead and serviced without dismounting. The apparatus should be built into a single unit, if possible, in order to minimize installation costs and troublesome interconnecting cables. Ordinary plug connectors frequently collect condensed moisture and should be avoided whenever possible. Terminal strips with soldered connections are much to be preferred for marine applications.

The 50-watt equipment for large yachts and coastwise vessels is shown in Figs. 1, 2, and 3. The main unit is composed of a transmitter and a receiver mounted together on a common frame which is secured flat against a bulkhead or on the floor with pivot hinges on the top or either side and bracket bolts on the opposite side. This permits the unit as a whole to be swung out for access to the rear. Access to the apparatus on the front where all tubes and relays are located is obtained by removing the front covers. Doors in the front covers of the receiver and transmitter provide ready access to the controls used for channel selection and frequency adjustment.

The transmitter at the top has a crystal selector switch, a knob for tuning the output circuit, and a plate-current meter for indicating the correct tuning. Microphone and receiver jacks are provided so the equipment may be operated locally, if desired, by the use of a handset equipped with suitable plugs. The receiver at the bottom has a crystal beating-oscillator selector switch and a tuning control for the radio-frequency circuits. The indicating dials may be marked with station identification for ready reference.

A choice of nine channels may be made from this position for use at one or more remote control units such as those shown in Fig. 1. A tenth frequency may be selected by relays operated by a momentary contact switch on the right side of the control unit when the handset is removed from the switchhook and the power supply is turned on with the switch on the left.

As shown in Fig. 1 two control units are available, one for wall mounting and one for table use. Each unit has a special panel mounting a power switch, a boat-to-boat frequency-selector switch, an indicating light which shows when the power is turned on, and a volume control for the receiver. The bell operated by

the signaling selector in the radio receiver is mounted inside the control unit. Several of these control units may be connected in parallel to provide telephone service from different parts of the boat. The motor-alternator shown in Fig. 1 provides sufficient power at 120 volts alternating current to supply the equipment.

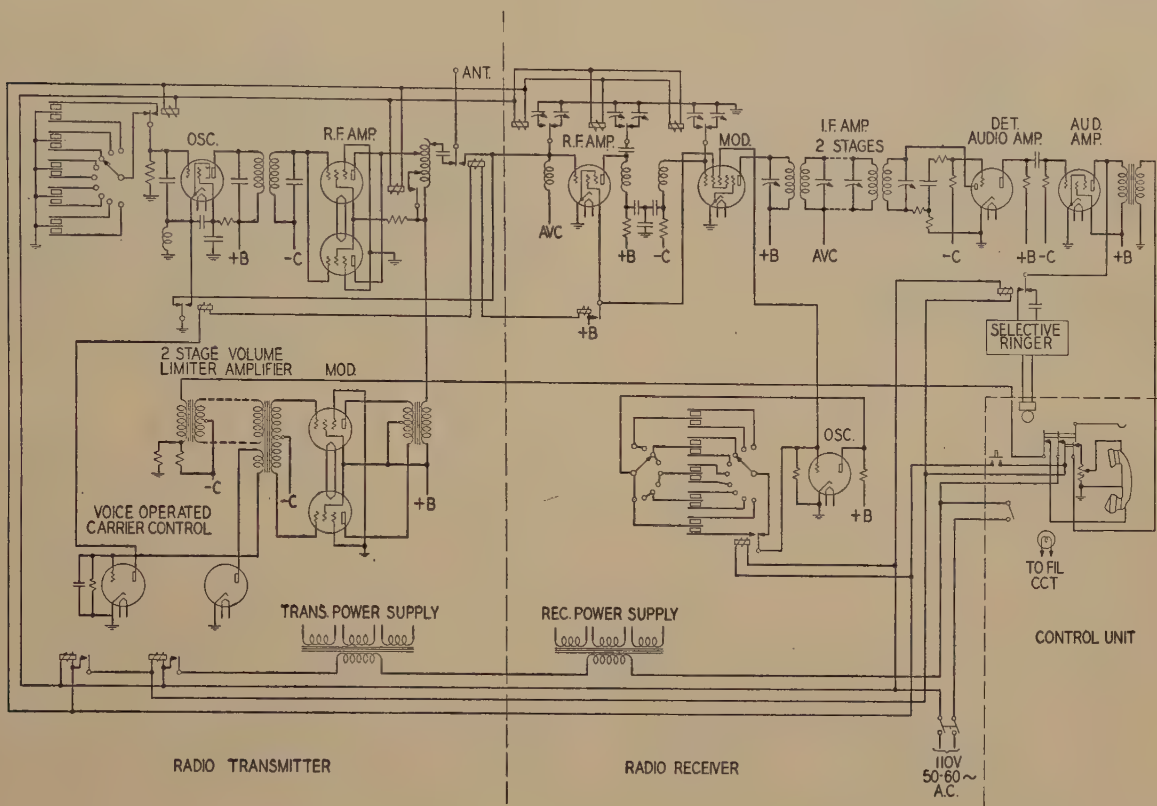


Fig. 4—Simplified schematic diagram of 50-watt equipment.

A simplified schematic diagram of the entire equipment is shown in Fig. 4. The radio transmitter uses one Western Electric 350A tube as a crystal-controlled oscillator driving two Western Electric 339A pentode tubes in parallel to produce 50 watts of carrier output power. The interstage circuit required no adjustment over the entire frequency range (2100 to 2800 kilocycles) and the output circuit is tuned over a wide range of antenna characteristics by adjusting a single roller-type coil. After the set is installed and tuned to the boat's antenna it is seldom necessary to change the antenna tuning adjustment since the ship station frequencies, for use in coastal and harbor service, are all close enough together (2100 to 2200 kilocycles) not to require retuning and the boat-to-boat frequency (2738 kilocycles) is selected from the remote control position and the tuning is automatically corrected by a relay which short-circuits a portion of the antenna-circuit inductance. The last radio-frequency stage is modulated on plates and screens by a push-pull audio-frequency power amplifier using another pair of No. 339A pentode tubes. This amplifier is driven by a two-stage push-pull audio-frequency amplifier using RCA 6L7 and 6N7 tubes. The amplifier gain is automatically controlled to give substantially constant output over a 30-decibel range by a gain-control circuit using a 6H6 diode

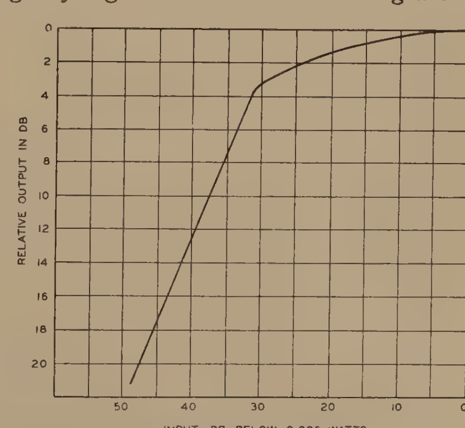
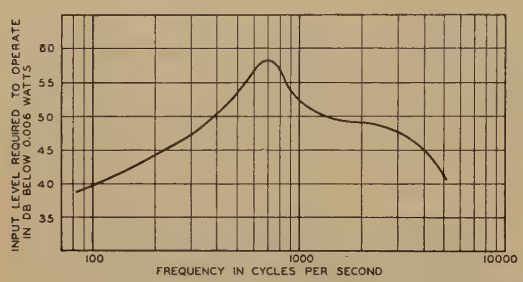


Fig. 5—Volume-limiter characteristic; 24A radio transmitter.

rectifier tube. This characteristic, shown in Fig. 5, makes it unnecessary to have an adjustment for the speech input to the transmitter.

The transmitter is also equipped with a voice-controlled circuit using a 6C5 tube and relays to switch the antenna from receiving to transmitting condition and start the carrier within a few milliseconds after the speaker starts talking. The sensitivity of this circuit is peaked in the speech range to minimize false operations as shown in Fig. 6. The circuit is arranged



Eig. 6—Vodas sensitivity characteristic; 24A radio transmitter.

to be held in the transmitting condition for about two tenths of a second after the speaker stops in order to avoid unnecessary clipping between words and syllables.

The radio receiver used with this equipment is a superheterodyne set using nine tubes in the following

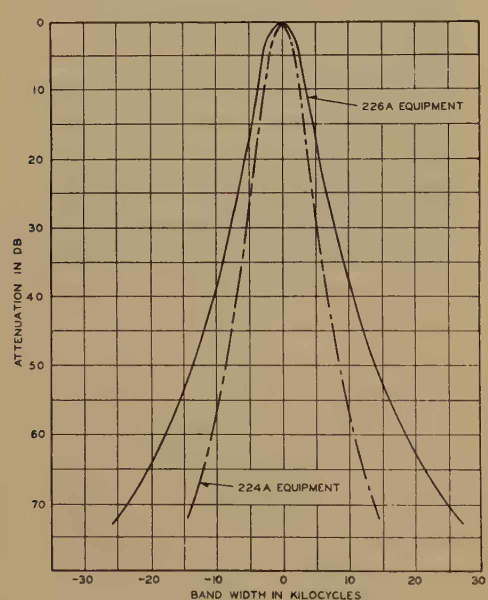


Fig. 7—Selectivity characteristics; both receivers.

circuit arrangement: radio-frequency amplifier, first detector, crystal-controlled beating oscillator, two stages of intermediate-frequency amplification, a combined second detector and audio-frequency amplifier, an automatic-volume-control tube, an audio-frequency output amplifier, and a rectifier tube. Three radio-frequency gang-tuned circuits, one ahead of the first tube and two following it, provide adequate radio-frequency selectivity. The full tuning range of these circuits is adjusted for 2450 to 2800 kilocycles in order to broaden greatly the tuning of the circuits. A separate tuning condenser is provided for each tuned circuit to care for the remotely selected boat-to-boat frequency. These condensers and the proper beating-oscillator crystal are connected into the circuits by relays operated by the boat-to-boat switch in the control unit.

The two-stage intermediate-frequency amplifier operating at 385 kilocycles with the radio-frequency selectivity described provides an over-all selectivity shown in Fig. 7. The automatic-gain-control circuit working on the intermediate- and radio-frequency amplifiers provides a sensitivity and volume-control characteristic shown in Fig. 8.

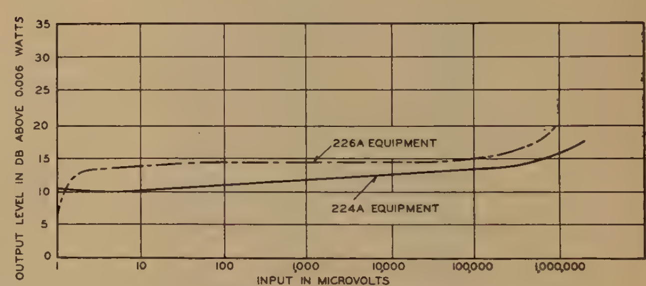


Fig. 8—Automatic-volume-control characteristics; both receivers.

The entire equipment operates from a 120-volt, 60-cycle supply with separate transformers and rectifiers for each unit. Approximately 150 volt-amperes are required in the stand-by condition, 350 volt-amperes while receiving and ready to transmit, or 500 volt-amperes while transmitting. The use of low-voltage rectifier tubes and filters for plate supply in the transmitter was made possible by the new Western Electric No. 339A pentode tube which operates from a 500-volt supply.

The 15-watt equipment for small yachts and harbor craft is shown in Figs. 9 and 10. This equipment is much simpler and smaller than the 50-watt set. The transmitter and receiver are built together in the same housing and use a common power-supply rectifier. This unit is intended for bulkhead or table mounting and for local control. It is equipped with a loud speaker for monitoring and does not contain a ringer but may be used with a ringer mounted separately. The standard telephone switchhook and handset mounted on the left side of the set may readily be removed and mounted in a more convenient location to suit the particular installation. A push button in the handset serves to transfer the power supply from

the receiver to the transmitter and at the same time to switch the antenna.

The schematic circuit of the complete equipment is shown in Fig. 11. The transmitter uses two Western Electric 350A tubes, one as a crystal-controlled oscillator and another as an output power amplifier, and two RCA 6L6 tubes in push-pull arrangement as an audio-frequency amplifier to plate-modulate the last radio-frequency stage. The receiver uses the same circuit as the 50-watt set but with one less intermediate-frequency stage and a simpler automatic-gain-control circuit. Power supply for both transmitter and receiver is obtained from the same rectifier using a 5Z3 rectifier tube. The total power taken from a 120-volt, 60-cycle supply is 115 volt-amperes in the stand-by position for the receiver only or 250 volt-amperes when the transmitter is operating.

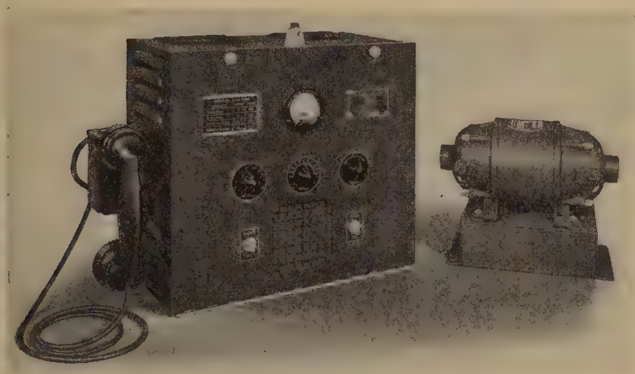


Fig. 9—15-watt marine radiotelephone equipment No. 226A.

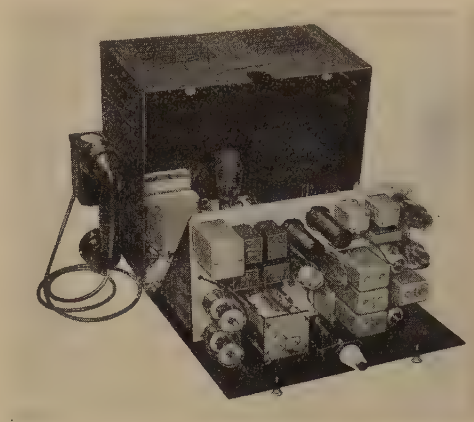


Fig. 10—15-watt set opened for inspection.

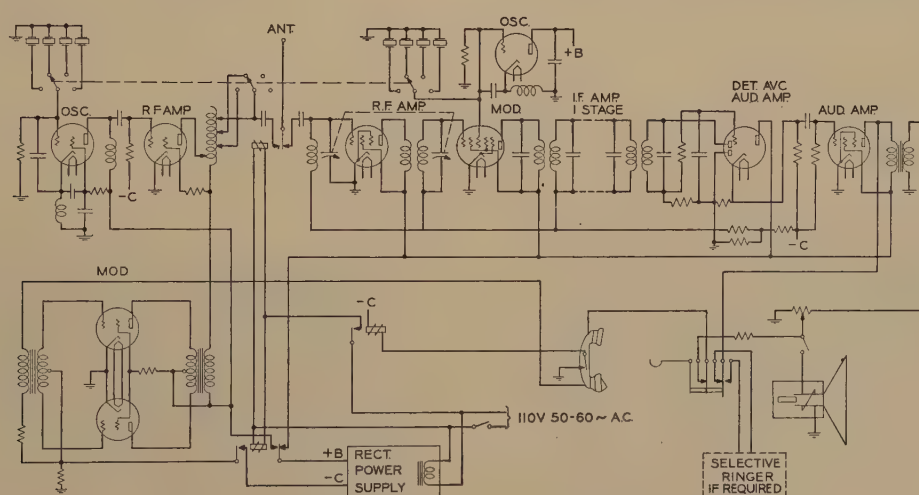


Fig. 11—Simplified schematic diagram of 15-watt equipment.

Remotely Controlled Receiver for Radiotelephone Systems*

H. B. FISCHER†, ASSOCIATE MEMBER, I. R. E.

Summary—*New radio receiving equipment for shore station used in ship-to-shore telephone circuits has been developed. This equipment is designed to operate on a remotely attended basis and may be located a considerable distance from the telephone terminal equipment. The radio receiver forming a part of the equipment has a codan circuit which operates reliably under high noise conditions and does not require adjustments to compensate for variations in the noise level. An emergency battery power-supply system is provided which is automatically connected to the receiver when the primary alternating-current power supply fails. Power failures are indicated at the telephone central office. A test oscillator which is controlled from the telephone central office is provided which may be used to check the operation of the receiver or to measure the frequency deviations of the incoming signals. The various apparatus units are mounted in two weatherproof cabinets which may be fastened to the same telephone pole which supports the receiving antenna.*

Introduction

FOR a number of years ship-to-shore telephone circuits have been in successful operation and over this period of time numerous changes have been made in the type of equipment used and in the general operating procedure. At the present time, it is considered desirable to transmit the radio-frequency carrier from the ship transmitter only when speech is transmitted and to suppress the carrier in the intervals between speech. This results in a saving of power, a reduction in interference, and also enables switching relays to be controlled by the carrier at the shore terminal.

Automatic volume control was provided on the receivers originally used for this service to reduce the effects of fading. When a set having automatic volume control is used with cut-carrier operation a number of problems arise which are not present in a system operating on a continuous-carrier basis. The gain of the receiver increases to its maximum value when the carrier is removed and, therefore, causes the set to amplify any received noise to such an extent as to be objectionable to a subscriber or to operate the control relays and thus prevent operation of the transmitter. To prevent this, a device known as a codan was developed and added to the receivers. This unit disconnects the receiver output whenever no carrier is received and reconnects the receiver output to the telephone circuit whenever a carrier is present. This circuit improvement reduces the number of false operations of control relays due to noise during intervals of no speech, and greatly improves the general operation of the circuit. The type of codan generally used consists of a direct-current amplifier and a relay. The amplifier input is connected to the automatic-volume-control circuit of the receiver and its output is connected to the relay which disconnects the receiver from the circuit when the received signal falls below a predetermined value. Conversely, when the signal rises above this predetermined value the receiver output is reconnected to the circuit. The operating sensitivity of the codan is usually adjusted by the technical operator so that the receiver just fails to operate on noise. Since the noise level fluctuates over rather wide limits it is necessary to readjust the codan sensitivity manually in order to obtain optimum performance at all times.

New Receiving Equipment

In the interests of effecting additional improvements in service new shore-station receiving equipment for unattended operation has recently been developed. This equipment not only embodies all of the recent developments in receiver circuit design, but also takes advantage of improvements in the associaated apparatus units which permit simplifications in the operation of the system. Modern transmitters have precise crystal control of the frequency and it is no longer necessary to provide a continuously tunable receiver and have an operator adjust it to the transmitter frequency. The new receiver is arranged for crystal control of the beating oscillator, so manual tuning is eliminated.

A new codan circuit which operates over a wide range of noise levels without readjustment by a technical operator eliminates the need for continuous monitoring. Furthermore, an automatically connected emergency power supply insures operation even when the primary alternating-current power supply fails. These factors make it possible to operate the receiver on an unattended basis and therefore it may be installed at a remote point free from man-made interference where satisfactory operation will be obtained with signals of lower intensity than would otherwise be possible.

This equipment known as the No. 223A radio receiving equipment consists of the following components:

No. 23A radio receiver
No. 289A dynamotor panel

* Decimal classification: R570×R361.2. Original manuscript received by the Institute, January 31, 1939. Presented before I.R.E. Convention, New York, N. Y., June 18, 1938.
† Bell Telephone Laboratories, Inc., New York, N. Y.

No. 291A test oscillator panel
No. 292A control panel
KS-10023 weatherproof cabinet
KS-10024 weatherproof battery box

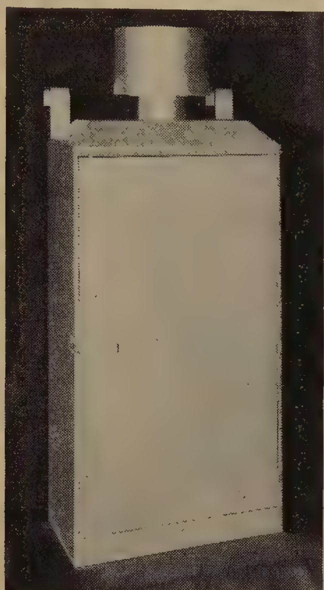


Fig. 1—KS-10023 weatherproof cabinet.

The No. 23A radio receiver is a fixed-frequency superheterodyne unit operating at any pretuned frequency in the range of 2 to 22 megacycles. It pro-

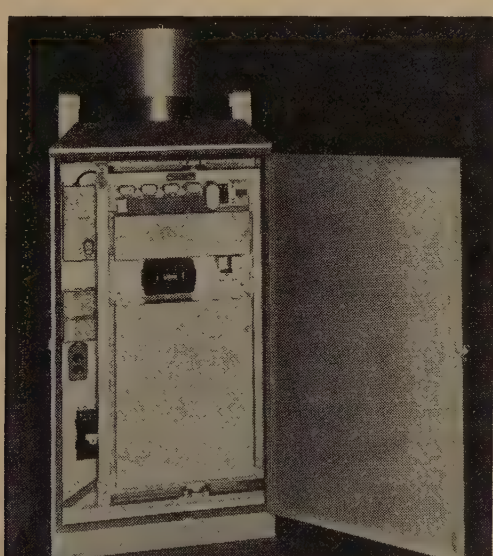


Fig. 2—KS-10023 weatherproof cabinet showing apparatus.

vides a high degree of sensitivity and selectivity, a wide range of automatic volume control, and the frequency stability of a crystal-controlled beating oscillator. Its most noteworthy feature is the selective codan circuit which is an integral part of the receiver. For local operation where the receiver unit is located within a building no other facilities are required but for remote installations a number of

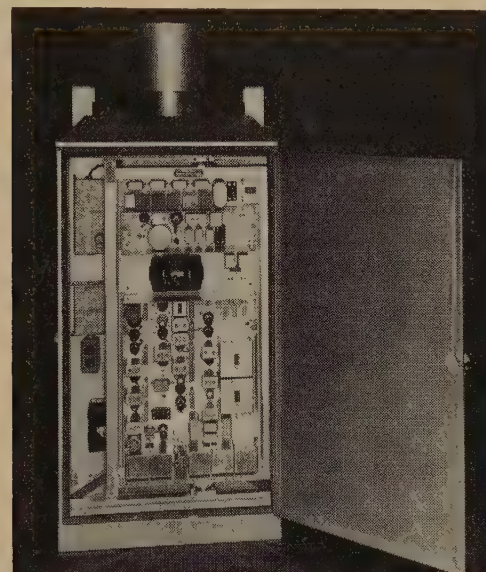


Fig. 3—View of apparatus in cabinet with front dust covers removed.

auxiliary panels may be used to provide the exact type of service required.

Whenever the alternating-current power supply

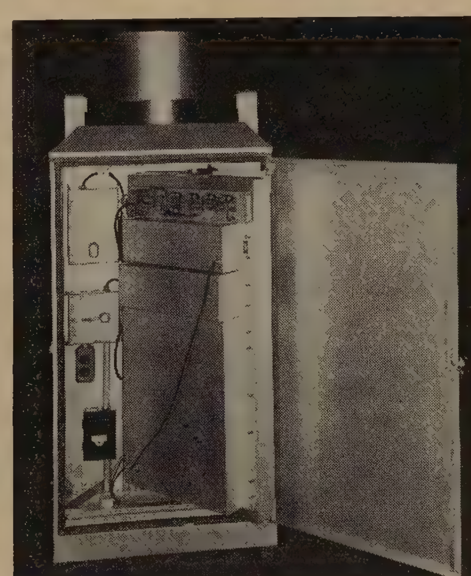


Fig. 4—View of apparatus in cabinet with hinged rack rotated showing rear view.

fails, the equipment is automatically shifted to the emergency battery by relays in the No. 289A dynamotor panel. These relays transfer the vacuum-tube

filaments and the crystal heater from the alternating-current supply to the battery supply, apply the battery to the primary of the dynamotor which furnishes the high-voltage supply, and transfer the high-voltage circuits of the receiver from the rectifier supply to the dynamotor supply.

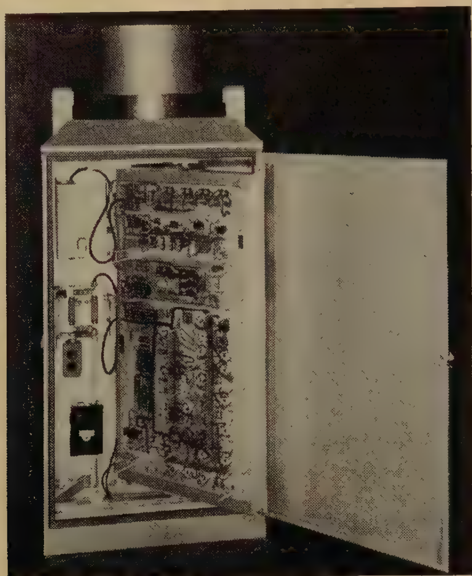


Fig. 5—Rear view of apparatus with dust covers removed.

The control office is notified when power failure occurs through the action of the No. 292A control panel. The circuit arrangement of this panel provides an indication when the receiver is switched to the emergency supply and when it is again switched back to the regular alternating-current supply.

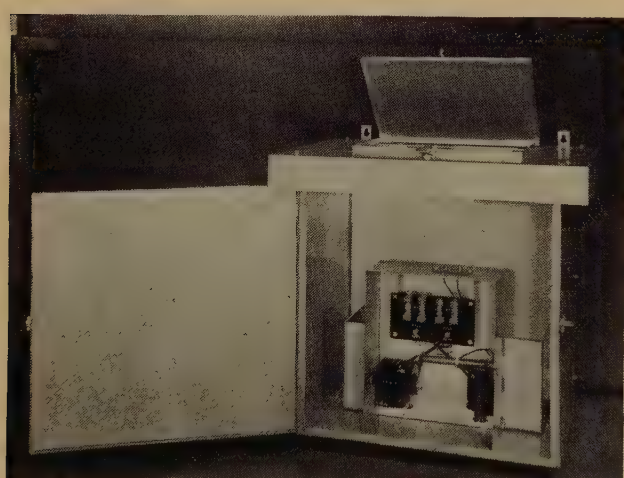


Fig. 6—View of KS-10024 weatherproof battery box with doors open.

The No. 291A test oscillator panel contains a crystal-controlled radio-frequency oscillator and a 1000-cycle audio-frequency oscillator which may be used to supply the energy for modulation. In order that the remote operator may check the operation of the receiver the test oscillator is modulated and if the receiver is operating properly a 1000-cycle tone is heard. When observing the frequency deviation of any received signal the test oscillator is unmodulated and the resulting audio-frequency beat note between the incoming carrier and the test oscillator carrier may be measured at the control point. Remote control of the test oscillator is provided by direct-current operation over the same telephone line used to carry the audio-frequency output of the receiver to the control station.

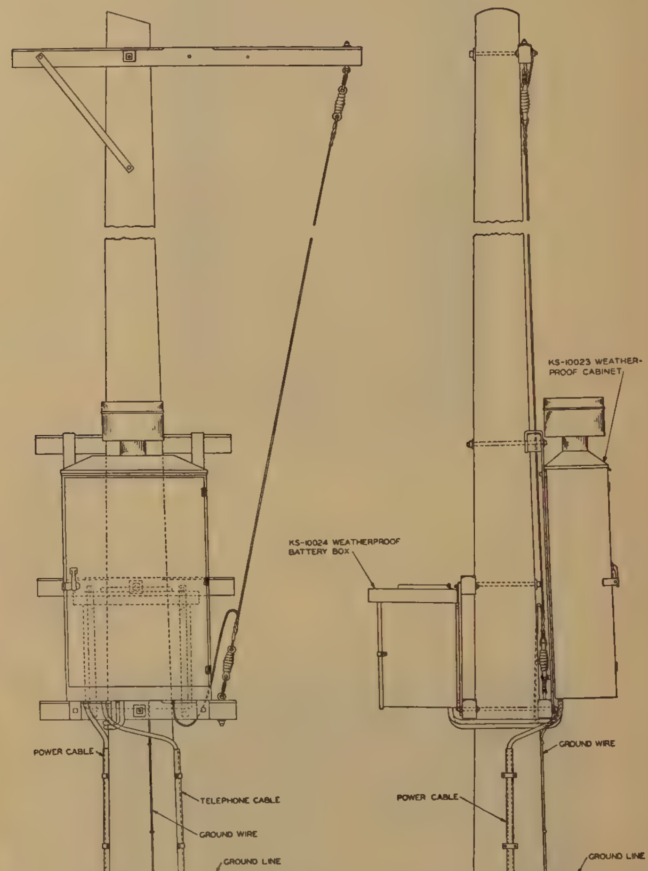


Fig. 7—KS-10023 weatherproof cabinet and KS-10024 weatherproof battery box mounted on pole.

When used as a remotely controlled receiver the equipment generally will be located outdoors and therefore a suitable weatherproof housing has been provided. Fig. 1 shows the KS-10023 weatherproof cabinet in which the receiver and the associated panels are mounted. A combination power switch and fuse, a double-convenience power outlet and radio-frequency filters for the power and telephone lines are a part of this cabinet. Fig. 2 is a view of the

cabinet with the door open and in Fig. 3 the front dust covers of the apparatus have been removed so as to show the front of the receiving equipment. The various panels are mounted on a 19-inch supporting frame similar to a short section of relay rack. This frame is fastened to the cabinet by hinged supports so that the assembly may be swung out as shown in Fig. 4, in order that the rear of the panels are accessible for servicing. Fig. 5 also shows the wiring side of the panels with the rear dust covers removed.

The emergency battery is housed in the KS-10024 weatherproof battery box which also contains a trickle charger to maintain the battery in a fully charged condition. Fig. 6 shows a view of the battery box with the cover open.

The No. 223A radiotelephone equipment will generally be mounted on a telephone pole which also supports the receiving antenna, as shown on Fig. 7. This greatly simplifies the problem of making a satisfactory installation at a remote location.

Circuit Description

A simplified schematic of the receiver is shown in Fig. 8. Three preselector circuits are provided before the grid of the radio-frequency amplifier tube *V*1 in order that a high degree of radio-frequency selectivity may be obtained, if the requirements of any particular installation make this necessary. The plate circuit of this tube is coupled to the first detector *V*2 by two additional tuned circuits. The beating oscillator tube *V*3 is a double-triode tube. One section is controlled by the quartz crystal and for frequencies above about 7500 kilocycles the second triode section is used as a frequency multiplier.

The plate circuit of the first detector is coupled to the first intermediate-frequency amplifier tube *V*4 by a double-tuned filter, and a similar filter couples this tube to the second intermediate-frequency amplifier tube *V*5. Another filter in the plate circuit of *V*5 feeds the full-wave series-type peak limiter tube *V*6, while the output of this tube energizes the last intermediate-frequency filter.

The diode section of the duplex-diode-triode tube *V*7 is the speech-branch detector and is fed from the last intermediate-frequency filter, while the triode section of this tube is the first audio-frequency amplifier. The detector and the direct-current amplifier for the delayed, amplified automatic-volume-control circuit is also a duplex-diode-triode vacuum tube *V*8 energized from the last intermediate-frequency filter. A level-control potentiometer is provided in the grid circuit of the audio-frequency output tube *V*9.

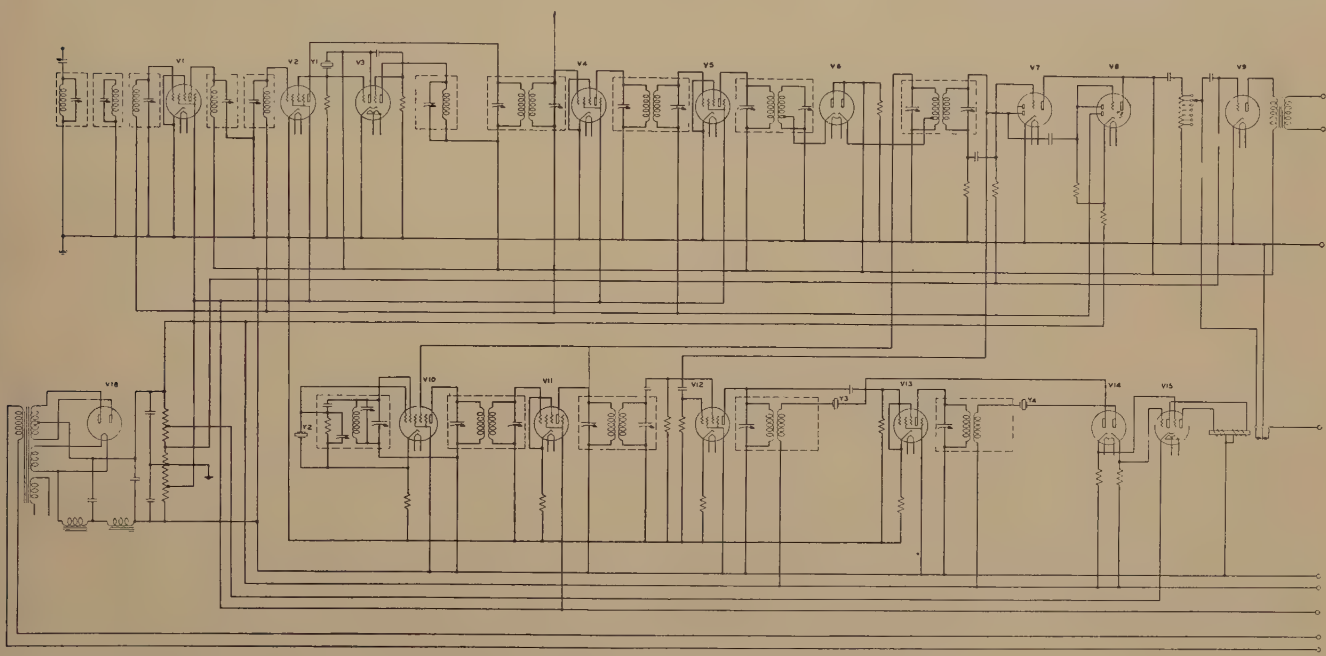


Fig. 8—Simplified schematic of No. 23A radio receiver.

The codan circuit of this receiver is energized from the final intermediate-frequency filter. Part of the intermediate-frequency output of this filter is fed to the control grid of the pentagrid converter tube *V*10 and the control grid of the mixer tube *V*12. The oscillator section of the pentagrid converter *V*10 is crystal-controlled by a precise quartz crystal operating at a frequency of 300 kilocycles, and consequently the 455-kilocycle intermediate-frequency input to this tube is modulated. The 755-kilocycle modula-

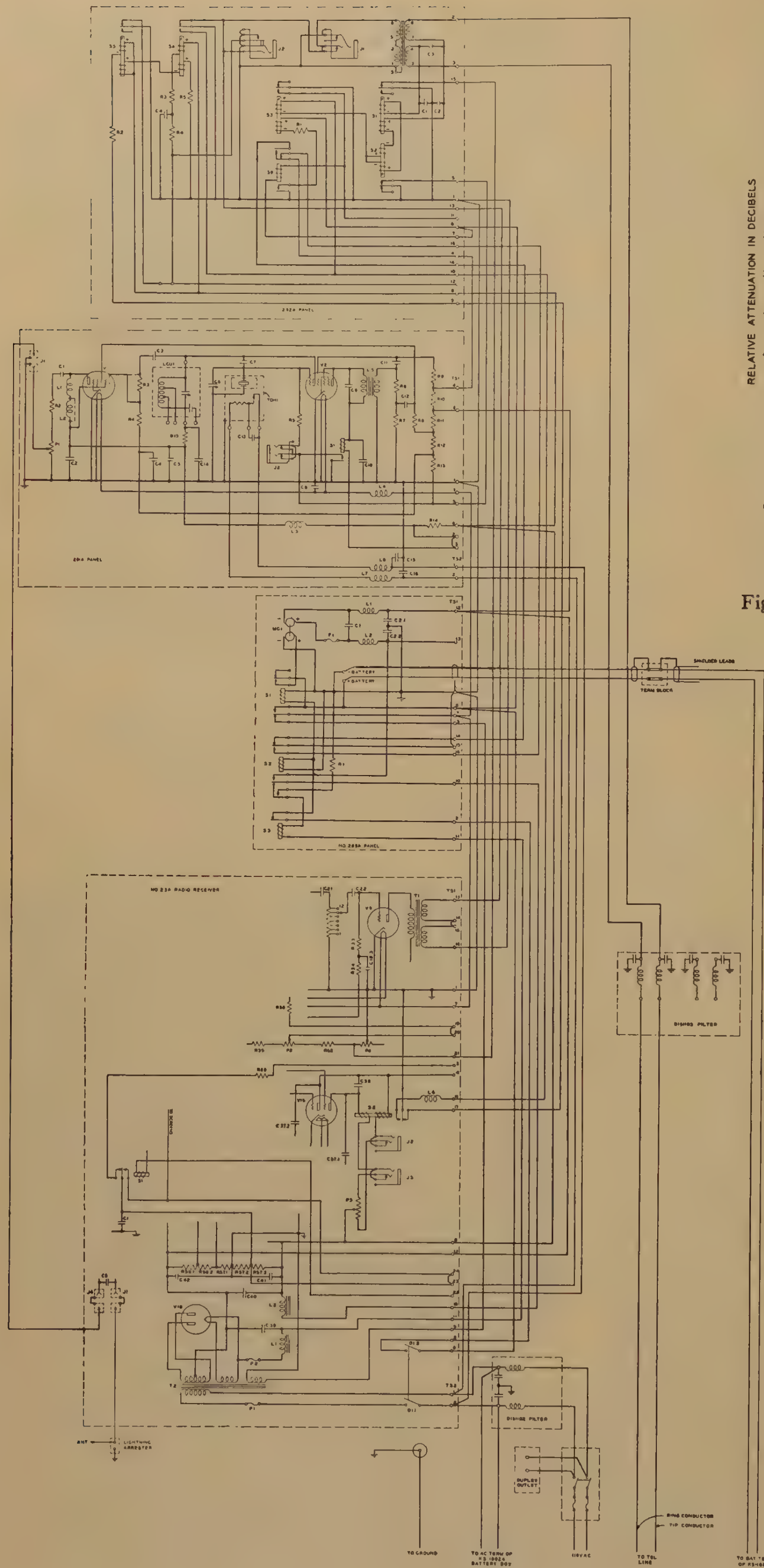


Fig. 9—Interconnection diagram of No. 223A radiotelephone equipment.

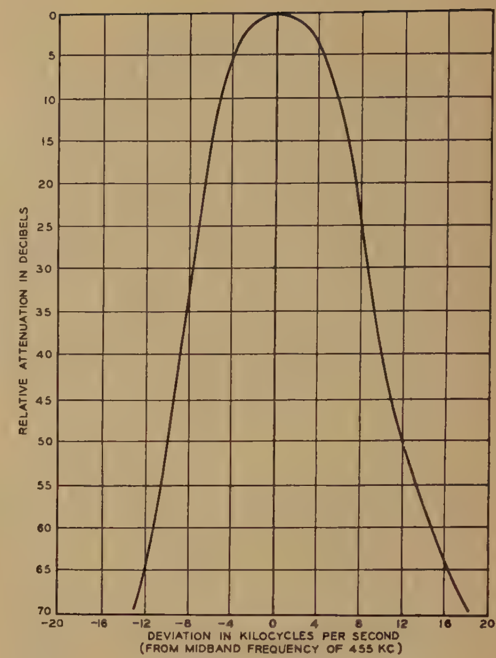


Fig. 10—Intermediate-frequency characteristic of No. 23A radio receiver.

tion product of the converter $V10$ is selected by a filter and amplified by $V11$. Another filter feeds the 755-kilocycle component to the mixer grid of $V12$. The intermediate frequency of 455 kilocycles is also fed to the control grid of $V12$ and therefore there is a 300-kilocycle component in the plate circuit of the tube. When a signal is present in the intermediate-frequency amplifier, this system of remodulation produces a new component having a carrier frequency of 300 kilocycles, with side bands corresponding to those associated with the normal intermediate-frequency signal.

The plate circuit of $V12$ energizes two filter networks employing highly selective quartz filters. One filter passes only a narrow band of frequencies corresponding to the incoming carrier, while the other filter eliminates this narrow band but passes a wider band corresponding to the normal band width of the intermediate-frequency system. The outputs of these two filters are rectified in the two diode rectifiers in $V14$. These outputs operate two direct-current am-

plifiers in the twin-triode tube $V15$ and the outputs of these amplifiers serve to operate differentially the polarized relay which controls the audio-frequency output of the receiver. During the intervals when no carrier is being received very little energy passes through the narrow-band filter and the noise passing through the wide-band filter keeps the relay in the operated position and short-circuits the audio-frequency output channel. When a carrier is received,

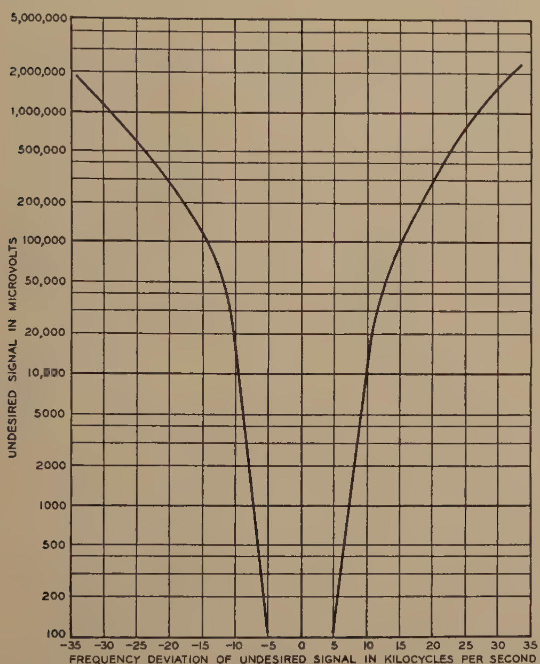


Fig. 11—Two-carrier radio-frequency-selectivity characteristic of No. 23A radio receiver. Desired signal, 1000 microvolts at 2208 kilocycles. Interference from undesired signal, 20 decibels below, 30 per cent modulation, 400 cycles on desired signal. Undesired signal modulation, 30 per cent at 400 cycles.

the energy passing through the wide-band-filter channel does not change appreciably, but that passing through the narrow-filter channel is considerably increased, due to the presence of the carrier. Consequently, the relay is released and the audio-frequency channel of the receiver is again energized.

Fig. 9 shows the interpanel wiring of the complete No. 223A radiotelephone equipment as well as the schematic circuits of the various panels.

Characteristics

A number of the more important operating characteristics of the receiver are shown in the various illustrations. The intermediate-frequency selectivity

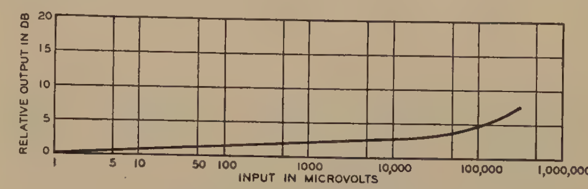


Fig. 12—Automatic-volume-control characteristic of No. 23A radio receiver.

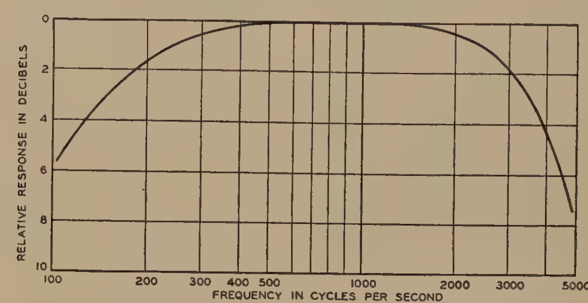


Fig. 13—Fidelity characteristic of No. 23A radio receiver.

of the set is shown in Fig. 10, while a 2-carrier radio-frequency-selectivity curve is shown in Fig. 11. This curve shows the permissible value of an interfering signal which will result in an output 20 decibels below the desired output. The automatic-volume-control characteristic (Fig. 12) shows a variation of about 4 decibels in output for a variation in input of 100 decibels. Consequently, a wide variation in signal input has a negligible effect on the output level. The audio-frequency fidelity characteristic is shown in Fig. 13. This characteristic represents a compromise between the wide pass-band which is desirable for high fidelity and the narrow band which is desirable for minimum noise.

Actual operating experience in a trial installation has shown that the performance of this receiver is highly satisfactory. In particular, the operation of the codan circuit is outstanding. No adjustment is required under a wide variety of noise conditions and reliable codan operation is obtained from circuits which are too noisy for commercial service.

Coastal and Harbor Ship Radiotelephone Service from Norfolk, Virginia*

W. M. SWINGLE†, NONMEMBER, I.R.E., AND AUSTIN BAILEY‡, FELLOW, I.R.E.

Summary—This paper deals with the engineering and operation of a radiotelephone service for harbor and coastal vessels in the Norfolk area. The instrumentalities discussed in companion papers are employed for this purpose.

First, the need for such a service is developed from maritime data concerning the character of water transportation. Then radio-coverage-survey results show that a radiotelephone station of only moderate power can reach satisfactorily the commercially more important parts of this area. A discussion of the power radiated from antennas on the smaller craft logically leads to the determination of suitable receiver locations.

The paper contains a general description of the plant installed at the Virginia Beach radio transmitting station, the radio receiving stations, and the control-switchboard positions in Norfolk, together with a discussion of the interconnection and interplay of these components to give service.

After telling of the facilities available for use by the switchboard operator, the paper concludes with a tracing of the steps followed in handling calls to or from vessels reached through the Norfolk marine operator.

THE coastal and harbor radiotelephone station WGB at Norfolk, Virginia, is the latest in a series of stations being provided by the Bell System to make available a telephone service which permits the establishment of connections between any land telephone station reached through the Bell System and suitably equipped ships along the Atlantic, Gulf, and Pacific coasts. The Norfolk station, which was opened for public service on June 13, 1938, is of a type not previously employed. The engineering and operation of this station is of special interest in that it is the first station to use the new instrumentalities discussed in the companion papers published in this issue of the PROCEEDINGS. The availability of this new equipment permits the construction of stations requiring only a minimum amount of technical attendance and whose operating costs, it is expected, will be much less than previously possible.

Marine Transportation in the Norfolk Area

The Norfolk radio station is designed to serve ships operating in Hampton Roads, including its ports of Norfolk and Newport News, in the lower Chesapeake Bay, and along the Atlantic coast from approximately Cape May, New Jersey, to Cape Hatteras, North Carolina.

Hampton Roads, formed by the junction of three rivers as they flow into the Chesapeake Bay near the point where the bay enters the ocean, provides a spacious ice-free harbor and is one of the major ocean gateways of the eastern seaboard. Eight trunk-line railroads have freight terminals on the harbor. Coal, hauled from the mines of Virginia and West Virginia to water terminals in this area, constitutes the major item of traffic of three of these railroads and Hampton Roads is the largest coal port in the world.

The radiotelephone service provided by the Norfolk station will be useful in dispatching the tugs used to tow lighters and car floats between the various railroad and ship terminals located on the harbor. It will be valuable in operating passenger and automobile ferries and freight-car floats over the longer runs in the Hampton Roads area, such as the one-hour run between Norfolk and Newport News and the two- to three-hour run to the city of Cape Charles on the eastern shore of Virginia. Fishing boats operating along the coast and in the bay will be able to maintain contact with, and receive instructions and information from, their home offices. The ocean-going tugs engaged in towing coal to New England points will find that the establishment of the Norfolk station, together with the existing New York and Boston stations, permits them to obtain a radio service suited to their needs.

Coastal and harbor radio service is also used by owners and guests aboard pleasure craft to maintain contact with their homes and offices during cruises. The Norfolk station will serve not only the yachts whose home ports are in the Norfolk area but also any suitably equipped yacht which may be within its service area, such as those passing along the coast between northern and southern waters.

While coastal and harbor radiotelephone service is intended especially for boats operating in a harbor and its adjacent waters and for coastwise vessels not required by law to be equipped with radiotelegraph, the larger passenger vessels in the coastwise service may find it desirable to supplement their radiotelegraph by making radiotelephone service available for the use of their passengers. The feature of direct two-way communication, as provided by the radiotelephone service, will appeal to the passengers of such boats.

* Decimal classification: R510. Original manuscript received by the Institute, September 28, 1938. Presented before I.R.E. Convention, New York, N. Y., June 18, 1938.

† The Chesapeake and Potomac Telephone Company of Virginia, Richmond, Va.

‡ American Telephone and Telegraph Company, New York, N. Y.

Selection of Transmitter and Receiver Locations

As a preliminary to the establishment of a coastal and harbor station, two kinds of information, obtainable from transmission tests, are needed. First, the coverage of the shore transmitter must be tested to be sure that a radio transmitter at any site tentatively selected on the basis of experience[1] will adequately reach ships in the area to be served; and second, transmission tests must be made at several places to determine strategic locations for radio receivers. Bell Telephone Laboratories engineers made the radio transmission tests for the Norfolk station using a portable transmitter operating on 2398 kilocycles together with a test car[2] equipped for field survey work.

The geographical layout of the harbor and the adjoining coastal area, the service requirements of the prospective subscribers to the service, and the radio transmission characteristics at the frequencies allocated to this service are controlling factors in selecting the location for the transmitting and receiving equipment. Due consideration must also be given to other factors, largely economic, such as availability of land and proximity to existing power and telephone lines. Because of the higher attenuation[1] of the radio path over land than over water and the especially high attenuation of land adjacent to the transmitter or receiver, satisfactory transmission range can be obtained with the low powers used in this service only when the shore transmitter and receiver are located so that the paths to the boats will be over water in so far as practical.

As no location in the Norfolk area would permit an entirely overwater path, a transmitter location was selected where the land would cause the minimum impairment. The transmitter location (Fig. 1) between Virginia Beach and Cape Henry provides an overwater path to boats on the ocean where the greatest range is required. The path to boats on Chesapeake Bay includes about a mile of land at the transmitter end, but required coverage in this direction is less than toward the ocean. The path to boats in the Elizabeth River, where many of them dock, is almost entirely over land. However, the maximum distance to be covered in this direction does not exceed the limit for satisfactory overland transmission.

While a satisfactory transmitter location was selected, there is no single receiver location which would provide adequate coverage because of the lower powers used for the ship transmitters and the generally poorer antenna-installation conditions on board ships. However, because of the lower cost of receiving stations, it is practicable to provide more than one receiver, each located so as to obtain, in so far as needed, an overwater path to the portions of the area served by it. Each shore receiver should be located so as to avoid areas with high local noise.

Based upon the transmission and noise measurements made at several tentative locations, the initial receiver of the Norfolk station was installed at the

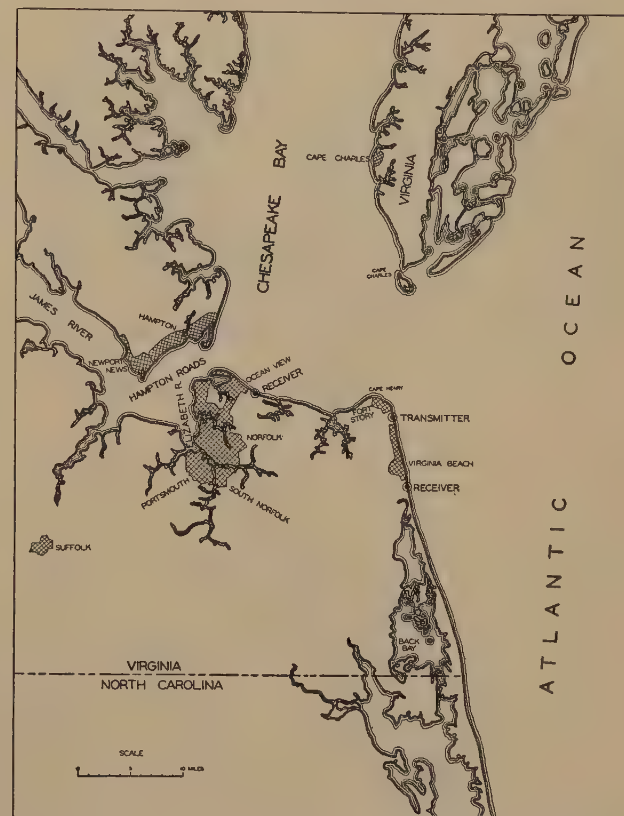


Fig. 1—Norfolk harbor area and locations of coastal and harbor transmitter and receivers.

point shown in Fig. 1 near Ocean View. This receiver is centrally located in the area to be served and has an overwater path from ships in the bay, some land in the path from Hampton Roads, but has a considerable amount of land in the path from boats on much of the ocean.

The receiver is a development model of a new type of receiver and as soon as commercial models become available, a second receiver will be installed at the point shown in Fig. 1 south of Virginia Beach so as to obtain the greatest possible ocean coverage. It is expected that the Ocean View receiver will adequately cover the Elizabeth River area, but should experience indicate that the transmission loss is too

[1] C. N. Anderson, "Attenuation of overland radio transmission in the frequency range 1.5 to 3.5 megacycles per second," Proc. I.R.E., vol. 21, pp. 1447–1462; October, (1933).

[2] G. M. Hafner, "A test car for marine radio telephone surveys," *Bell Lab. Rec.*, vol. 14, pp. 94–98; November, (1935).

high, a third receiver located in the vicinity of the river will be installed.

Service Area

The coverage area for the Virginia Beach transmitter is shown in the cross-hatched area in Fig. 2. Within this area a ship should be able to receive reliably from the 400-watt shore station during the daytime. At night, the variability of noise and signal field are so great that, while under adverse conditions, the reliable coverage is much less, nevertheless, valuable service is frequently given at distances far outside the coverage area shown.

Ships using coastal and harbor radiotelephone service generally employ transmitters of 50 watts power or less and space limitations on the smaller craft considerably reduce the antenna efficiency. Although the service area will depend in large measure on the ship installation, some estimate can be made of what might be expected with good installations of 50-watt and 15-watt radiotelephone sets. With shore receivers near Ocean View and Virginia Beach, the daytime service area for 50- and 15-watt ship transmitters is indicated on Fig. 2 as inside the solid and dotted lines, respectively.

Remote Control of Transmitter and Receivers

While the employment of more than a single receiving point has considerable advantage in making the service available to boats operating in a larger area, the telephone company must operate more receivers and connect them all into a single control point. The development of the new remote-control receiver for coastal and harbor service, which has been described in another paper,[3] has materially simplified this problem. By use of this new receiver, it is possible to extend the essential controls back to Norfolk over wire circuits and to concentrate receiver operation at a single location.

The transmitter is likewise operated by remote control over telephone circuits from Norfolk. The several transmitter control features have been described in more detail in another paper.[4]

The remote control circuits from the transmitter and receiver are connected at the Norfolk central office to control equipment located in the same room

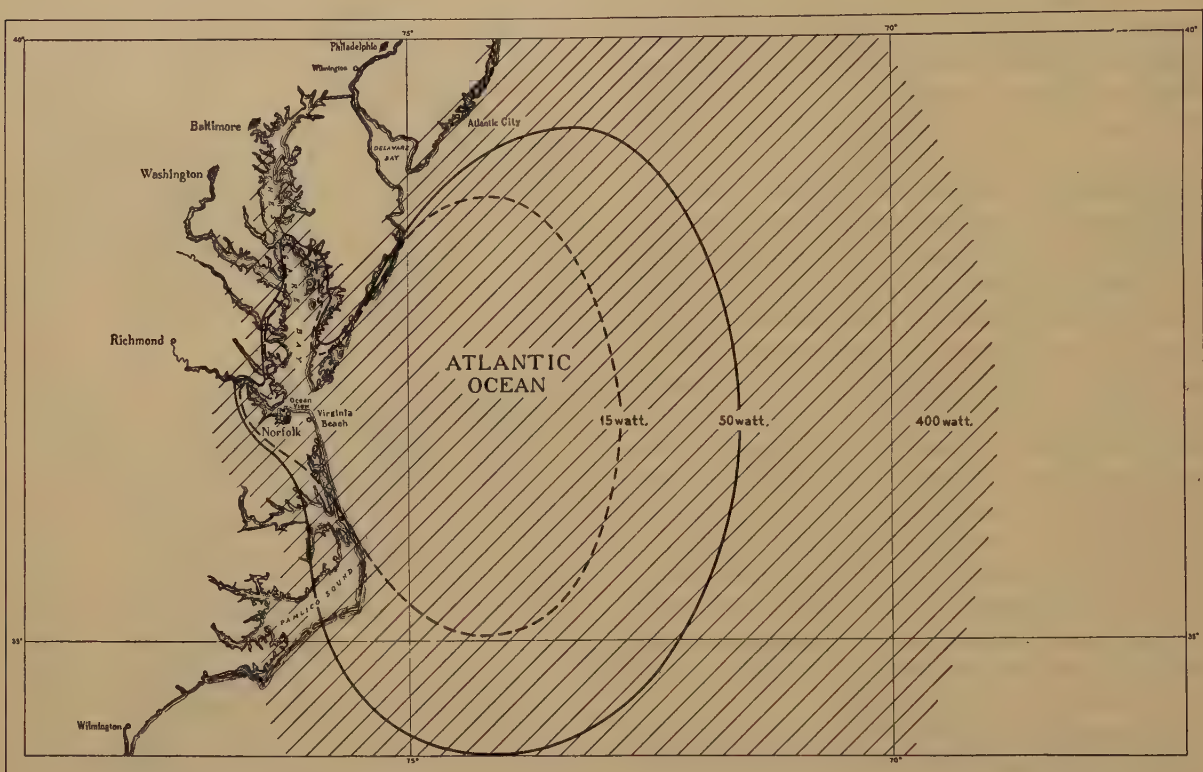


Fig. 2—Service areas of 400-watt shore transmitter and 15- and 50-watt ship transmitters.

[3] H. B. Fischer, "Remotely controlled receiver for radiotelephone systems," Proc. I.R.E., this issue, pp. 264–269.

[4] C. N. Anderson and H. M. Pruden, "A radiotelephone system for harbor and coastal service," Proc. I.R.E., this issue, pp. 245–253.

as the terminal and testing equipment associated with the long-distance telephone circuits. After passing through the control equipment, the radio circuit is terminated at the Norfolk long-distance switchboard. The location selected for the control equipment is the logical one since it is the central point in the network of telephone wires serving the Norfolk area, a skilled maintenance force is on duty at all times, and the long-distance switchboard is in the same building.

Radio Transmitting Station

As the site of the transmitting station is in an area where the beginning of building development has increased the price of land, the land purchased was as small as consistent with providing an adequate ground system. Three lots, providing a plot 150 feet by 150 feet, were purchased about 1000 feet back from the ocean edge so as to obtain security from possible storms and erosion. The ground system consists of 60 radial copper wires 0.165 of an inch in diameter buried in the sand at a depth of about 8 inches. The ground system has an average radius of 90 feet. The radial wires are brazed to a ring bus consisting of a 1/2-inch copper tubing formed in a circle about 7 feet in diameter around the base of the antenna.

Fig. 3—Transmitter building and 80-foot shunt-excited vertical radiator.

The antenna (see Figs. 3 and 4) is a shunt-excited[5] vertical radiator consisting of a commercial galvanized steel self-supported flagpole, less the fittings for flying a flag, with 80 feet of pole above ground. The pole is connected, near its base, to the ground system by four lengths of copper tubing extending from the pole to the ring bus. The radiator is excited through a lead from the transmitter connected to the pole about 20 feet above the ground.

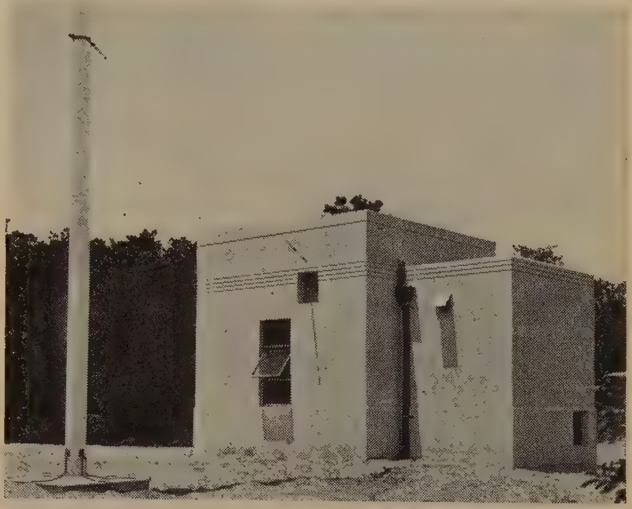


Fig. 4—Rear view of transmitter building and lower portion of radiator.

The shunt-excited radiator, as selected for this station, has essentially the same efficiency as a series-excited one of the same structural type, but is cheaper due to the omission of insulating arrangements at the base. It is estimated that its cost was little, if any, more than for antennas of the same efficiency but of different structural types, such as a flat-top antenna between wood poles or a vertical wire suspended from a wood pole, when all factors are considered, including the more expensive arrangements for coupling a series antenna to the transmitter and the immunity of the shunt-type from lightning damage. Moreover, as the transmitting station is located in a developing residential area, it was very desirable to use a shunt-excited flagpole for the antenna because of its better appearance.

The transmitter and associated equipment are housed in a small tile-lined, reinforced-concrete building shown in Fig. 3. The building has two small rooms, one room, $11\frac{1}{2}$ by $11\frac{1}{2}$ feet, is just large enough to house the transmitter and rectifier, a work bench, and a spare-parts cabinet, and the other room, 7 by 8 feet, is designed to house a proposed gasoline engine driving a 5-kilowatt 3-phase alternator for use during failures of commercial power. A building of reinforced concrete is particularly suitable in this location be-

[5] J. F. Morrison and P. H. Smith, "The shunt-excited antenna," Proc. I.R.E., vol. 25, pp. 673–696; June, (1937).

cause of its stability against shifting of the sand around the foundation and other effects of storms which may be severe in this area.

The radio transmitter employed at the Virginia Beach transmitting station is a 400-watt crystal-controlled-type similar to those designed for use at aviation ground stations and is adjusted to feed the shunt-excited antenna at a frequency of 2538 kilocycles. The crystal control maintains this frequency to a high degree of precision. The power supply for the radio transmitter is obtained from a rectifier unit designed as a companion piece of equipment. These units, together with an auxiliary amplifier and certain wire terminating and control equipment, are installed in the transmitter building as shown in Fig. 5.

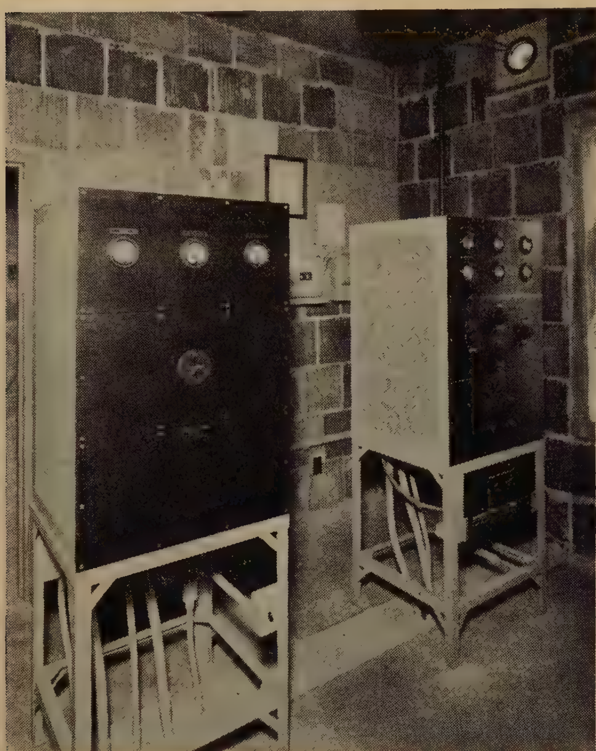


Fig. 5—Radio transmitter, rectifier, and auxiliary equipment.

Similar radio transmitter installations are already in use at other Bell System coastal and harbor stations.[6,7] The modifications in the particular installation at Virginia Beach are to care for the shunt-excited antenna employed and to provide means to control remotely a "stand-by" adjustment. In the "stand-by" condition, the filaments are operated at about 80 per cent of their rated current and the plate voltage is removed from the equipment. When the transmitter is required for service, it can be put "on the air" in a few seconds. The switchboard operator in Norfolk puts up a cord in the normal manner as with any telephone call. This action energizes the control circuits to the transmitting station which operate a relay to bring the filaments up to normal current and apply the plate voltage. If, instead of beginning with the "stand-by" condition, the radio transmitter had been shut down, about 30 seconds would have been required to get "on the air."

Radio Receivers

All of the equipment comprising a radio receiver installation is mounted on a single pole. The pole, as shown in Fig. 6, extends 50 feet above ground.

Fig. 6—Radio receiver installation.

The pole carries a vertical antenna wire, a box housing the radio receiver and associated equipment (Fig. 7), a box housing a storage battery and charger for emergency use (Fig. 8), and a ground consisting of about 5 feet of wire fastened spiraled on the base of the pole.

The radio receiving equipment is the remote-controlled receiver recently designed for coastal and

[6] E. B. Hansen, "Ship-to-shore radio in Puget Sound area," *Trans. A.I.E.E.*, vol. 54, pp. 828–831; August, (1935). Digest in *Bell Sys. Tech. Jour.*, vol. 14, pp. 708–712; October, (1935).

[7] F. A. Gifford and R. B. Meader, "Marine radiotelephone service," *Com. and Brdcst. Eng.*, pp. 9–11; October, (1935). Digest entitled "Marine radio telephone service for Boston harbor," in *Bell Sys. Tech. Jour.*, vol. 14, pp. 702–707; October, (1935).

harbor service. The quartz-crystal control incorporated in the receiver assures that it is at all times tuned to 2142 kilocycles, the transmitting frequency of the boats served by the Norfolk system.

In case of failure of the commercial alternating current normally supplied the receiver, service is continued by an automatic change-over to the emergency power-supply equipment mounted on the pole. This equipment includes a trickle-charged 6-volt storage battery supplying filament power and also driving a dynamotor from which the higher direct-current potentials required are derived. A test oscillator, turned on by the change-over equipment, transmits a power-failure signal to the Norfolk office so the maintenance forces may arrange for the restoration of the commercial power and for replacing batteries if the duration of the failure is likely to exceed the 8-hour period during which the battery will operate the receiver.

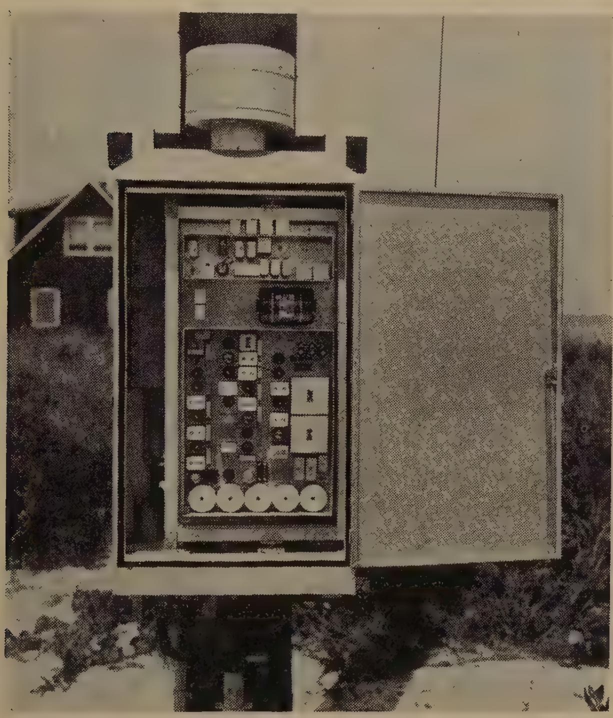


Fig. 7—Radio receiver and associated equipment.

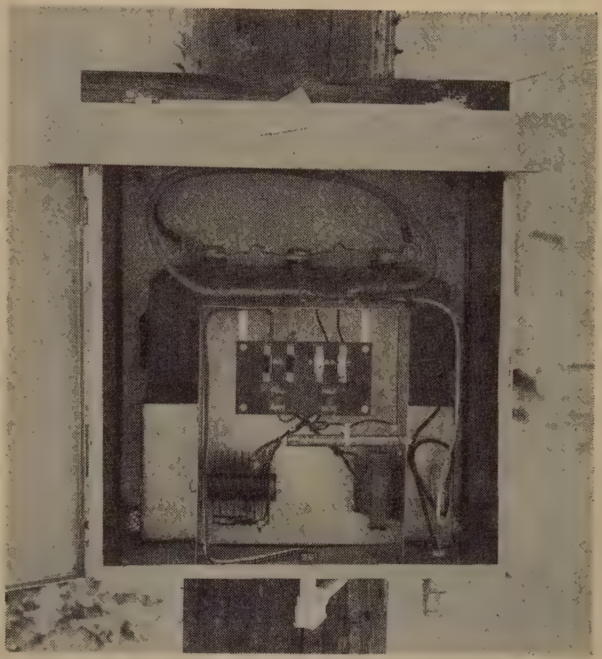


Fig. 8—Emergency power supply for receiver.

The test oscillator, which can be remotely controlled from the terminal, permits checking the frequency received from ships and provides a means for remotely testing the operation of the radio receiver.

Control Terminal

Fig. 9 shows the control terminal installed in the Norfolk toll test room. In the upper portion of the bay is a radio receiver used to monitor the output of the Virginia Beach transmitter and a crystal-controlled oscillator, by means of which the transmitter frequency may be observed. The equipment in the center of the bay provides facilities for controlling and testing the operation of the transmitter and the two receivers and for interconnecting the one-way radio transmitting and receiving circuits with the two-way telephone circuit to the switchboard In

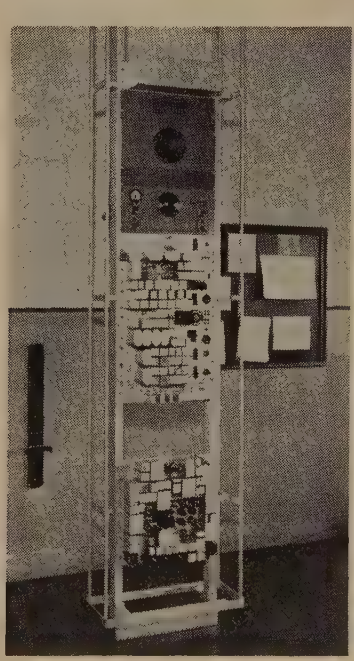


Fig. 9—Norfolk control terminal.

the lower portion of the bay are two amplifiers, the one in the receiving branch having a fixed gain as the volume level is held substantially constant by the receiver automatic volume control, while the one in the transmitting branch is a vogad[8] (voice-operated-gain-adjusting-device) whose gain varies with the speech volume so as to keep the transmitter fully modulated and, at the same time, avoiding overmodulation. The detailed functions and operation of the control terminal equipment are described elsewhere.[4]

The licensed radio operator responsible for the operation of the system is stationed at this point where he may check and control the operation of both the transmitter and receiver, and may supervise and

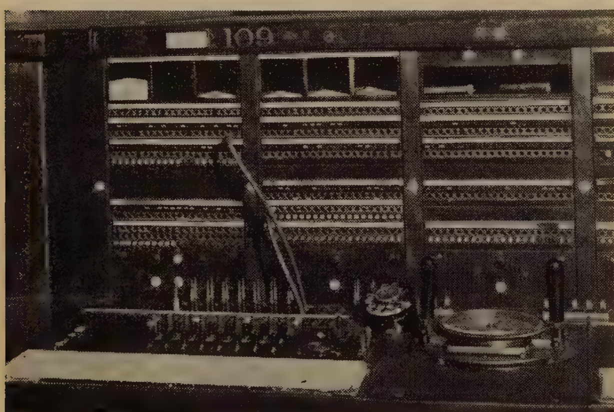


Fig. 10—Marine position of Norfolk long-distance switchboard.

provide any assistance required by the traffic operator at the switchboard. A transmitter cutoff key is provided in the control terminal so that the licensed radio operator may turn off the transmitter at any time and, in doing so, prevent its being turned on by the switchboard operator in accordance with the usual procedures described below.

Procedure in Handling Calls

Calls through the radio station are handled by the marine operator at the position of the Norfolk long-distance switchboard shown in Fig. 10. The position was equipped for radio service by adding a key, lamp, and dial (the one mounted flush) to the right of the usual key-shelf equipment and terminating the radio circuits on the jacks in the face of the board. The dial and associated key are used to control the pulses of 600- and 1500-cycle tone transmitted to operate the signaling selectors on the boats. The lamp, whose operation is controlled by a relay in the monitoring receiver of the control terminal, indicates to the operator whether or not the shore transmitter is emitting carrier. In the face of the switchboard, two jacks and a lamp are provided for each receiver. The jack designated "line" is used on calls between a ship and a land station, while the jack designated "by-pass," used on ship-to-ship calls, is arranged so that the insertion of a plug connects the output of the receiver to the input of the transmitter. Thus, on ship-to-ship calls, the Norfolk land station serves as a frequency changer by reradiating at 2538 kilocycles (the ship receiving frequency) whatever is transmitted by a ship on 2142 kilocycles.

The procedure of the traffic operators in handling radio calls is generally similar to that used for ordinary long-distance calls. When a ship originates a call, the receipt of its carrier at the shore station causes a lamp to light over the jack associated with the receiver on which the signal is being received and also turns on the shore transmitter. The operator answers the call by inserting an ordinary switchboard cord in the jack and then extends the call, using the other end of the same cord circuit, to the called station over ordinary local or long-distance telephone circuits as required. Calls originating on land are routed to the Norfolk marine position where the operator starts the transmitter by inserting a cord in one of the radio jacks and, when the key-shelf lamp indicates that the carrier is on, she dials the assigned code of the called ship. The selective signaling equipment on the ship dialed rings a bell and the connection is ready for use as soon as the call is answered by lifting the handset on the boat. If the boat called is not equipped for selective signaling, the ringing key in the cord circuit is operated momentarily to transmit over the radio the 1000-cycle tone interrupted 20 times a second which is used for ringing on certain types of long-distance circuits. This serves as an attention signal and is reproduced in the waiting loud speakers of the boats not equipped for selective signaling. The operator then announces the name of the called boat and the connection is ready as soon as the called boat answers.

[8] S. B. Wright, S. Doba, and A. C. Dickieson, "A vogad for radiotelephone circuits," Proc. I.R.E., this issue, pp. 254–257.

Transient Response of Multistage Video-Frequency Amplifiers*

A. V. BEDFORD†, ASSOCIATE MEMBER, I.R.E., AND G. L. FREDENDALL†, ASSOCIATE MEMBER, I.R.E

Summary—*The response to a Heaviside unit voltage is set forth as the most logical and relevant criterion of the fidelity of video-frequency amplifiers.*

The part of the transient response that is governed by the high-frequency amplitude and phase-delay characteristics of amplifiers may be approximated closely by the steady-state response to a square wave having a suitable period and thus may be expressed in a Fourier series. Simplicity and rapidity of numerical calculation are the outstanding advantages of the steady-state formulation.

As an illustrative example of the method the transient response of several multistage compensated resistance-coupled amplifiers are computed. Considerable data helpful in the design of amplifiers of this type are presented. It is concluded: (1) The wave-shape distortion of a Heaviside unit voltage is accumulative as the number of stages is increased. (2) The value of the damping constant $K=R\sqrt{L/C}$ should lie between 1.51 and 1.61. (3) The resonant frequency $f_0=1/(2\pi\sqrt{LC})$ determines the slope of the wave front of the transient response. R is load resistance; C is the total shunt capacitance; and L is the compensating inductance in series with R.

It is proposed that the oscillographic response of video-frequency amplifiers and the associated transmission apparatus to a square wave be considered as a part of performance tests of future television systems.

Nature of the Problem

In television, intelligence is conveyed by the wave shape of voltage variations that originate in the television scanner. Such a signal is the electrical equivalent of variations in the intensity of illumination of the television subject along the scanning lines; and ideally the wave shapes of the variations in intensity and the associated variations in voltage should be the same. After much amplification, modulation of a carrier wave, and demodulation and more amplification in the receiver, the signal is translated back into variations in the intensity of illumination along the scanning lines in the cathode-ray receiving tube.

Clearly, the prime requisite of a video-frequency amplifier is the amplification of a signal, essentially transient in character, without appreciable modification of the intelligence borne by the signal; that is, the wave shape must be preserved within limits known to be tolerable. Distortionless amplification of transient voltages is obtained when the amplitude response and phase delay of the amplifier are independent of frequency from zero to infinite frequency. The essential video-frequency spectrum however is limited and extends from 60 cycles to at least 2.5 megacycles for the present 441-line interlaced scanning with a frame frequency of 30 cycles per second. Complete agreement on the upper limit of the spectrum does not exist; values ranging from 2.5 to 4.25 megacycles may be found in the literature. We know that amplifiers cannot and need not render distortionless amplification even over the video-frequency spectrum. Specific tolerances therefore are very important in design. The nature of the circuit elements in video-frequency amplifiers permits a complete division into low-frequency distortion and high-frequency distortion. We shall be concerned exclusively with the latter. Two criteria of high-frequency fidelity are in use.

The first concerns the sine-wave steady-state characteristics. (a) The amplitude response shall be substantially independent of frequency over the spectrum. (b) Differences between the phase delays at intermediate frequencies and at the upper frequency limit shall be small compared with the time required for the receiving aperture or spot to traverse a distance equal to the scanning-line pitch.

The second and less common criterion concerns the response to a Heaviside unit voltage commonly called the transient response. Three points are made in support of the unit voltage as a test signal. (1) An amplifier that responds properly to a unit voltage will amplify any video-frequency signal with acceptable fidelity. (2) If the response to a unit voltage is known, the response to any other transient signal may be calculated by the superposition theorem of operational calculus. (3) The effect of a given transient-response wave upon the picture structure can be determined by inspection.

We believe that tolerances can best be set by a direct examination of the response to transient voltages and that the second criterion is well suited for this purpose. The first criterion lacks directness and ultimately the second must be used as a check because the television video-frequency amplifier is fundamentally an amplifier of transient voltages. In this respect transmission requirements for television differ from those for sound.

A signal having the discontinouus character of a unit voltage is generated by a dimensionless scanning spot when scanning an infinitely sharp change in picture shade. In reality the scanning spot has an appreciable diameter and changes in picture shades are never infinitely sharp. As a consequence the most abrupt unidirectional change in voltage that can be

* Decimal classification: R363.1. Original manuscript received by the Institute, September 8, 1938.
† RCA Manufacturing Company, Inc., Camden. N. J.

generated by a scanning spot in present television systems occurs over an interval of about 0.15 microsecond.

The existing literature treats only one or two stages and methods of calculating the transient response have not been particularly expeditious for extension to multistage amplifiers. This is at once a handicap because the transmission characteristics of the entire television system (camera amplifier, studio amplifier, transmitter, and receiver) determine the fidelity. The video-frequency signal may pass through as many as forty stages of video-frequency amplification. A satisfactory method for obtaining the over-all response of a system must be readily adaptable

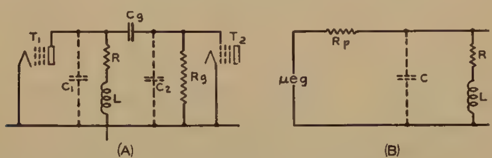


Fig. 1
(A) Compensated resistance-coupled amplifier.
(B) Equivalent circuit for high frequencies.

to the data available. In most instances the circuit elements of an amplifier may be treated as lumped constants and the response calculated. In other instances, the circuit constants are distributed in such a way that analysis in terms of lumped elements is not feasible. In the later case it is usually practicable to measure steady-state amplitude and phase-delay characteristics of full or reduced-scale models. The application of a completely satisfactory method should not require the services of a professional mathematician. Simplicity and dependability are very desirable.

We shall discuss briefly two classical methods for the calculation of the response to a unit voltage, the operational method and the Fourier integral formulation, and then develop in detail a preferred method. The compensated resistance-coupled amplifier has been frequently used in television systems and therefore will be used here as an example. Fig. 1(A) is a schematic diagram of connections. Fig. 1(B) is the equivalent circuit for high frequencies. The several components of distributed capacitance have been combined in a single value C. The inductance is added in order to maintain the response near the upper limit of the frequency spectrum at a higher level than possible in a simple resistance-coupled stage.

Using the conventional processes of operational calculus McLachlan[1] and others[2] have derived complete formulas for the response of a single amplifier to a unit voltage. Reference to McLachlan's paper is suggested for the details of the derivation which yields the following equation:

$$e(t) = g_m R\left[1 - \frac{e^{-\pi f_0 K t}}{K\sqrt{1 - K^2/4}} \sin (Mt + \theta)\right] \qquad (1)$$

in which

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$K = 2\pi f_0 RC$$

$$M = 2\pi f_0 \sqrt{1 - \frac{K^2}{4}}$$

$$\theta = \tan^{-1}\frac{K\sqrt{1 - K^2/4}}{K^2/2 - 1}$$

g_m = transconductance of the tube

$$R_p \gg R; \quad C_g \gg C_2; \quad R_g \gg \frac{1}{C_g\omega}.$$

(Changes in the original notation have been made for convenience.)

McLachlan mentions also the steps to be taken for obtaining the response of n stages but does not give the explicit result. In any event the method of operational calculus involves the use of specialized mathematical technique and entails a great amount of labor when there are several stages all identical or different. Its application is restricted to cases in which the circuit configuration and elements are known. This excludes the practical case in which experimentally determined amplitude and phase characteristics constitute the only available data as a consequence of distributed circuit constants.

The Fourier integral formulation provides an expression for the response to a unit voltage involving the steady-state amplitude and phase characteristics explicitly; namely,

$$e(t) = \frac{H(0)}{2} + \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{H(\omega) \sin [\omega t - \theta(\omega)]}{\omega} d\omega. \qquad (2)$$

$H(\omega)$ and $\theta(\omega)$ are the amplitude and phase characteristics respectively and ω is the angular frequency.

Although (2) is outwardly simple, its usefulness is much restricted in design work as the result of difficulties in the integration of the infinite integral. Usually an analytical integration presents great dif-

[1] N. W. McLachlan, "Reproduction of transients by a television amplifier," *Phil. Mag.*, vol. 22, pp. 481–491; September, (1936).

[2] O. Lurje, "Equalizing processes in wide-frequency range amplifiers," *Tech. Phys. U.S.S.R.*, vol. 3, pp. 229–248; March, (1936).

ficulty even to a professional mathematician. Graphical solution is unavoidably tedious on account of the oscillatory character of the integrand. After checking a few points on the transient-response curves in Fig. 11 by graphical integration of (2) we were convinced that the method is impracticable when a numerical answer is sought.

Steady-State Square-Wave Formulation

Before proceeding further it is necessary to distinguish between low-frequency and high-frequency distortion. Fig. 2(A) is a sketch of a typical transient response of a multistage amplifier (not necessarily a compensated resistance-coupled amplifier.) The interval $a-b$ over which the response is substantially zero is the effective time of transmission and does not represent distortion. During the interval $b-c$ the response increases from zero to a steady value after executing a damped oscillation (or an aperiodic variation). The failure of the response to rise sharply to 100 per cent, and remain there, is distortion. t_{b-c} will ordinarily be less than a half microsecond which is to say that the response during the interval $b-c$ is determined almost entirely by the amplitude and phase-delay characteristics in the upper region of the video-frequency spectrum. The capacitance of an amplifier for the reproduction of signals that correspond to the fine detail of a television subject is measured by the steepness of the wave front provided that the amplitude of the damped oscillation is low. During the interval $c-d$ there is a decline in response at a very slow rate which is governed by the low-frequency characteristics of the amplifier, that is, by coupling condensers, grid leaks, and plate-supply filters. This decline is too slow to be perceptible on the time scale in Fig. 2(A). The complete response shown in Fig. 2(A) may be considered as the limiting case of the response to a periodic square wave as the period becomes infinite. That is, if the square wave has the form

$$E(t) = \frac{1}{2} + \frac{2}{\pi}\left\{ \sin 2\pi f_p t + \frac{1}{3}\sin 6\pi f_p t + \frac{1}{5}\sin 10\pi f_p t + \cdots \right\}, \tag{3}$$

the response will be

$$e(t) = \frac{1}{2} + \lim_{f_p \to 0} \frac{2}{\pi}\left\{ A_1 \sin 2\pi f_p(t - D_1) + A_3 \sin 6\pi f_p(t - D_3) + A_5 \sin 10\pi f_p(t - D_5) + \cdots \right\}. \tag{4}$$

A_n and D_n are the steady-state amplitude response and phase delay for the frequency $n f_p$.

It is clear from physical considerations that a significant calculation may be carried out using a finite period. If the response during the interval $a-c$ is required, the period of the square wave is taken only long enough to permit the response to attain a substantially constant enduring value (that is, 100 per cent) before the beginning of the following half cycle. Hence in Fig. 2(B) the period is taken equal to 2 t_{a-c}.

Usually the effective time delay t_{a-b} is unimportant and only the response during the interval $b-c$ is required. In this instance a half period equal to t_{b-c} is sufficiently long as illustrated in Fig. 2(C).

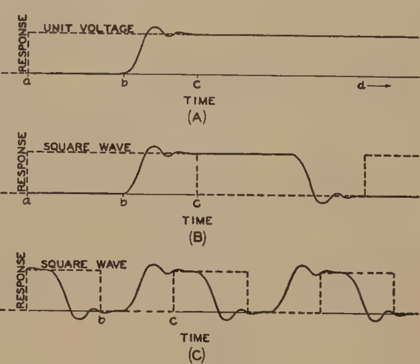


Fig. 2

(A) Transient response of typical multistage amplifier.
(B) Response to a square wave; period $=2t_{a-c}$
(C) Response to a square wave; period $=2t_{b-c}$.

The simplicity of the steady-state formulation as a means of numerical computation may be greatly compromised if a suitable choice of the period leads to a slowly converging series. Fortunately, this is not the case in the solutions presented below or in many other practical problems that we have treated. The labor involved in a specific instance is minimized when the duration of the transitory response is known approximately. An estimate may be made usually from inspection of the steady-state amplitude and phase characteristics. The utility of the Fourier series method can be demonstrated best by applications. To this end we have calculated the responses of a single-stage amplifier and several multistage compensated amplifiers. The treatment covers the interval $a-c$; no further consideration is given to the response over the interval $c-d$.

The Transient Response of Compensated Resistance-Coupled Amplifiers

The amplitude and phase characteristics of a single stage required for the series formulation are given by the following formulas:

$$\text{amplitude response} = g_m R \sqrt{\frac{1+B^2/K^2}{B^2K^2+(B^2-1)^2}} \tag{5}$$

$$\text{phase delay} = \frac{\theta}{2\pi f} = \frac{1}{2\pi f} \tan^{-1} (B/K)(K^2 + B^2 - 1) \quad (6)$$

in which

f = frequency

θ = phase shift (θ is positive when the output voltage lags the input voltage)

$B = f/f_0$

K, f_0, as defined for (1).

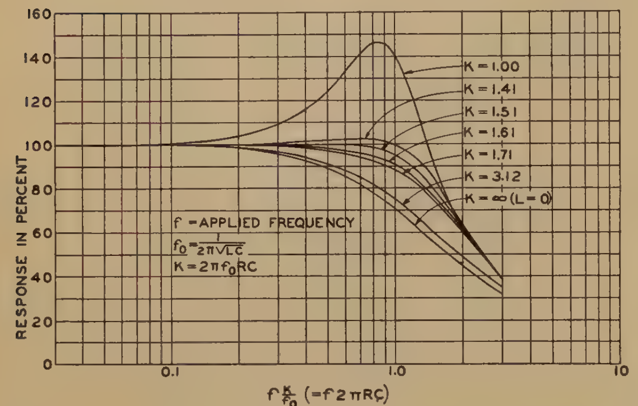


Fig. 3—Amplitude characteristic of one-stage amplifier.

If $f(K/f_0)$ is taken as the independent variable instead of f, a family of universal response curves and a family of universal delay curves may be drawn in which K is a parameter; and the change in variable will permit a rapid comparison of individual ampli-

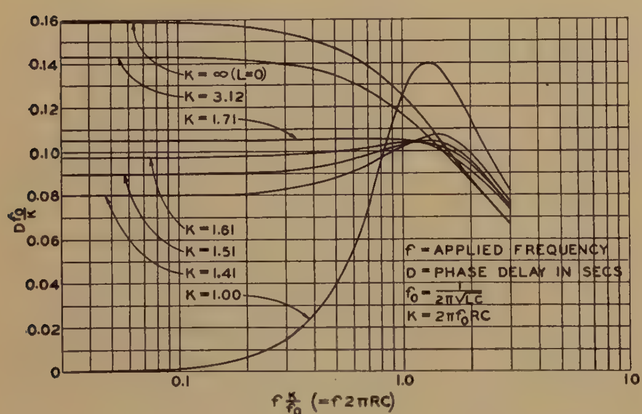


Fig. 4—Phase-delay characteristic of one-stage amplifier.

fiers having equal gains at low frequencies but different values of K. It will be shown later that K and f_0 are the essential circuit parameters. The condition for equal gains at low frequencies for different amplifiers characterized by K_1, K_2, K_3, etc., is that the product Rg_m shall be the same in all cases. That is,

$$R_1 g_{m1} = R_2 g_{m2} = R_3 g_{m3} \text{ etc.},$$

or

$$\frac{K_1}{f_{01}C_1} g_{m1} = \frac{K_2}{f_{02}C_2} g_{m2} = \frac{K_3}{f_{03}C_3} g_{m3}.$$

If

$$\frac{g_{m1}}{C_1} = \frac{g_{m2}}{C_2} = \frac{g_{m3}}{C_3},$$

then

$$\frac{K_1}{f_{01}} = \frac{K_2}{f_{02}} = \frac{K_3}{f_{03}}. \quad (7)$$

Hence at any given frequency the steady-state data corresponding to K_1, K_2, K_3, etc., may be read directly from Figs. 3 and 4 in which the condition of equal gain is automatically fulfilled when (7) holds. Inspection of these figures show that there is no

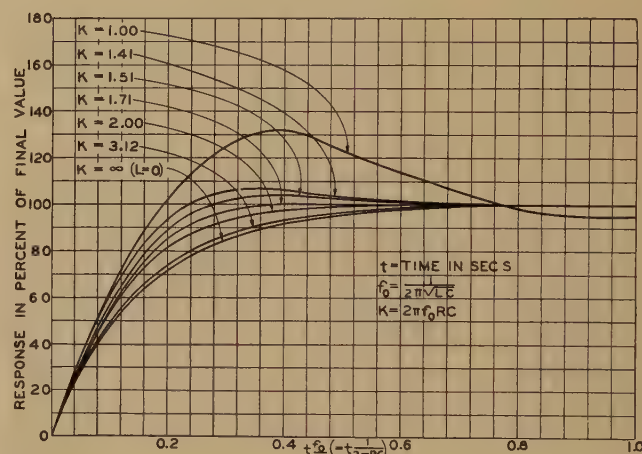


Fig. 5—Response of one-stage amplifier to a unit voltage.

value of K for which amplitude and phase-delay characteristics are simultaneously optimum. Among the curves in Figs. 3 and 4, that for $K = 1.71$ exhibits the least dependence of phase delay on the frequency and that for $K = 1.51$ (more exactly $K = 1.55$), the least dependence of amplitude response on the frequency.

Fig. 5 shows a family of curves of the response to a Heaviside unit voltage according to the rigorous equation (1). The family may be calculated easily by the Fourier series method drawing the necessary data from Figs. 3 and 4. The only step in the series development requiring judgment is the choice of a fundamental period, or rather half period, that just exceeds the time required for the response to attain a steady value. If a longer period is used, the convergence of the series is less rapid but the calculated response is not affected. If the period is too short, calculation reveals the misjudgment immediately by yielding a response curve that does not attain a steady value before the beginning of the next half

cycle. Fig. 5 is an aid in devising a guiding principle for finding a suitable period. Consider the curve of the family corresponding to $K=1.41$. The response does not vary more than ± 1 per cent from the final value after the elapse of $0.8\,K/f_0$ second. Hence it is expected that the significant part of the response to a unit voltage which occurs within the interval 0 to $0.8K/f_0$ second will be approximated closely by the response to a square wave that has a fundamental period equal to $2\times 0.8K/f_0$ or $2.26/f_0$ seconds; namely,

$$e(t) = \frac{1}{2} + \frac{2}{\pi}\left\{A_1 \sin 2\pi\frac{f_0}{2.26}(t-D_1) + \frac{A_3}{3}\sin 6\pi\frac{f_0}{2.26}(t-D_3) + \frac{A_5}{5}\sin 10\pi\frac{f_0}{2.26}(t-D_5) + \cdots\right\}. \quad (8)$$

If terms having amplitudes less than 0.01 are neglected, the finite series expression becomes

$$\begin{aligned} e(t) = \frac{1}{2} + \frac{2}{\pi}\Big\{ & 1.02 \sin\left(2\pi\frac{f_0}{2.26}t - 0.358\right) \\ & + 0.225 \sin\left(6\pi\frac{f_0}{2.26}t - 1.20\right) \\ & + 0.074 \sin\left(10\pi\frac{f_0}{2.26}t - 1.46\right) \\ & + 0.036 \sin\left(14\pi\frac{f_0}{2.26}t - 1.53\right) \\ & + 0.021 \sin\left(18\pi\frac{f_0}{2.26}t - 1.55\right) \\ & + 0.014 \sin\left(22\pi\frac{f_0}{2.26}t - 1.56\right) \\ & + 0.010 \sin\left(26\pi\frac{f_0}{2.26}t - 1.56\right)\Big\}. \end{aligned} \quad (9)$$

The agreement between $e(t)$ computed from the series (9) and $e(t)$ computed from the rigorous equation (1) is very good as shown in Table I. Near the discontinuities in the response at $t=0$ and $t=0.8K/f_0$ the series gives the poorest approximation. This is expected according to the theory of Fourier series.

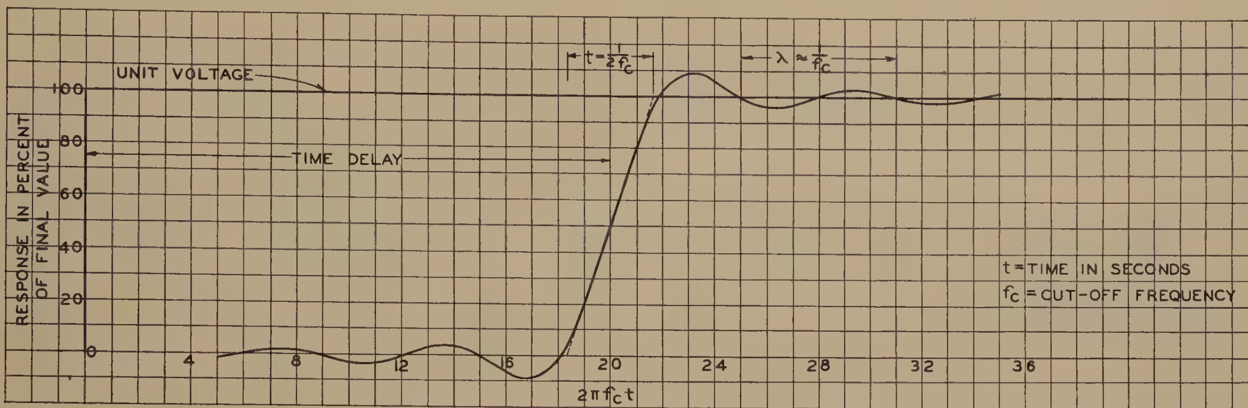


Fig. 6—Response of idealized amplifier to a unit voltage.

TABLE I

$\frac{tf_0}{K}$	$e(t)$ from equation (1)	$e(t)$ from equation (9)
0	0	0.04
0.05	0.30	0.30
0.10	0.60	0.58
0.20	0.93	0.92
0.40	1.06	1.07
0.60	1.02	1.02
0.80	1.00	0.96

Slide-rule accuracy.

Advance information was available in Fig. 5 for selecting a suitable fundamental period, but in useful applications of the series method such a convenient guide will be lacking. In the absence of other data, the proper fundamental frequency may usually be taken equal to the frequency at which the steady-state amplitude and delay characteristics cease to be sensibly independent of frequency. This is reasonable because distortion of the unit voltage input is caused by discrepancies in the characteristics. There are however exceptional cases in which this guide fails; one exception is the idealized amplifier. The amplitude and phase-delay characteristics of an idealized amplifier are independent of frequency in the range $0-f_c$ and the amplitude characteristic is 0 for frequencies greater than f_c. This is one of the few instances in which the Fourier integral (2) leads to a simple expression. Thus if the amplitude response $H(\omega)$ is set equal to 1 and the phase delay $\theta(\omega)/\omega$ to D, a constant independent of frequency, there results

$$e(t) = \frac{1}{2} + \frac{2}{\pi}\int_0^{2\pi f_c(t-D)} \frac{\sin x}{x}\,dx. \quad (10)$$

The definite integral is available in mathematical

tables.[8] Fig. 6 illustrates the response of the idealized amplifier having an arbitrary value of phase delay D equal to $20/2\pi f_c$ seconds. Obviously the wave shape does not depend upon D.

A suitable period for a Fourier series development would be chosen by trial. In general a period of insufficient length is detected immediately when the calculated response fails to attain a steady value during a half cycle.

Equation (10) indicates that the idealized amplifier responds before the unit voltage is applied. This discrepancy is a consequence of the physical incompatibility of the assumptions regarding $H(\omega)$ and $\theta(\omega)$. The idealized amplifier however is a good criterion

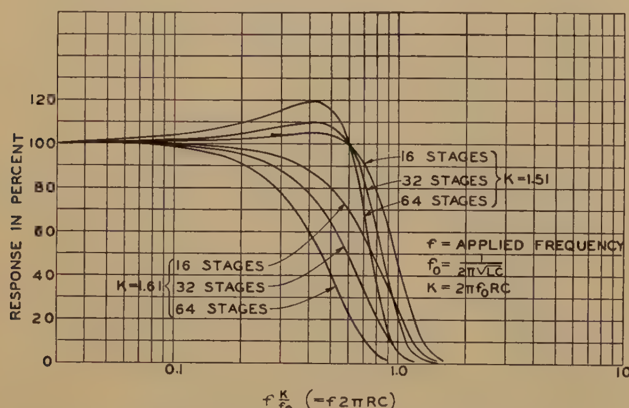


Fig. 7—Amplitude characteristics of multistage amplifiers.

of the optimum use of a given band width for the production of the maximum steepness of wave front.

Transient Response of Multistage Amplifiers

The simplicity and rapidity of calculation of the steady-state response to a square wave are especially valuable properties in the design of multistage amplifiers. A calculation of the stage-by-stage response of a 16-stage amplifier was laboriously made by repeated application of the superposition theorem of operational calculus before the utility of the series method was recognized. The result shown in Fig. 10 illustrates the accumulative distortion of a unit voltage input, a progressive decrease in the slope of the wave front, and a progressive increase in the high-frequency damped oscillation, which is typical of cascaded stages.

Fig. 11 is an extension of the Fourier series method to 16-, 32-, and 64-stage amplifiers. The required amplitude response and phase-delay characteristics shown in Figs. 7, 8, and 9 were derived from Figs. 3 and 4 by raising the amplitude response of one stage to the nth power and multiplying the phase delay by n. All transient-response curves are plotted with the correct effective time delay, that is, the fundamental periods of the series expansions exceeded t_{a-c}.

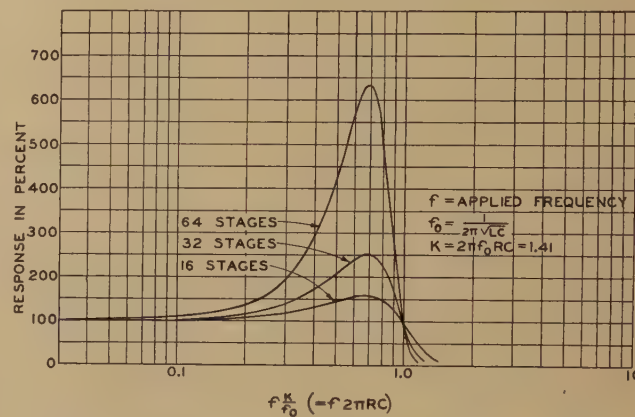


Fig. 8—Amplitude characteristics of multistage amplifiers.

Fourier series formed with shorter periods may express adequately the response during the interval $a-c$ as explained above. For example the response of

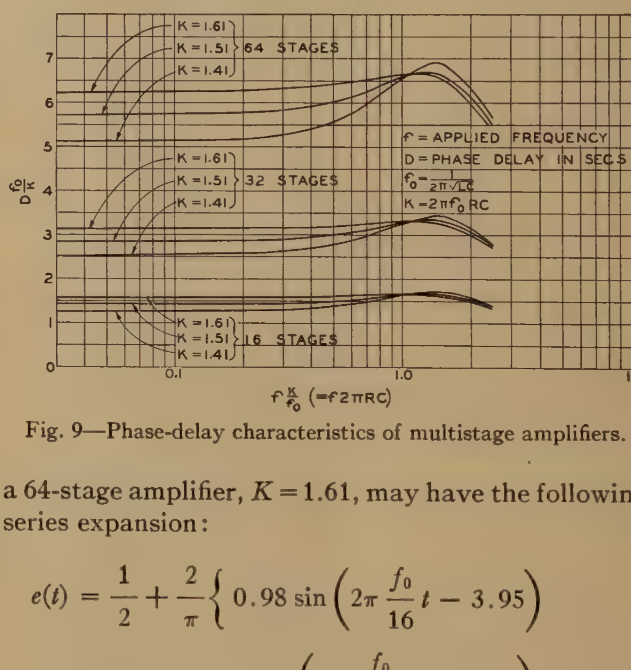


Fig. 9—Phase-delay characteristics of multistage amplifiers.

a 64-stage amplifier, $K=1.61$, may have the following series expansion:

$$
\begin{aligned}
e(t) = \frac{1}{2} + \frac{2}{\pi}\Bigg\{ & 0.98 \sin\left(2\pi \frac{f_0}{16} t - 3.95\right) \\
& + 0.256 \sin\left(6\pi \frac{f_0}{16} t - 11.99\right) \\
& + 0.08 \sin\left(10\pi \frac{f_0}{16} t - 20.29\right) \\
& + 0.016 \sin\left(14\pi \frac{f_0}{16} t - 28.88\right)\Bigg\}.
\end{aligned} \tag{11}
$$

The fundamental period $16/f_0$ is equal to two times the reciprocal of the frequency at which the steady-state amplitude and phase-delay curves begin to de-

[8] Jahnke-Emde, "Tables of Functions," Second revised edition, p. 78. B. G. Teubner, Leipzig and Berlin, (1933).

pend appreciably on the frequency as shown in Fig. 11.

Equation (11) defines a response similar to that illustrated by Fig. 2 (C) and does not yield automatically the length of the effective time delay. If the delay is required, steps justified by the following reasoning will lead to the correct value. The square wave shown in Fig. 2 (C) may be considered as the superposition of a series of positive unit voltages impressed at $t=0$, $-2t_{b-c}$, $-4t_{b-c}$, $-6t_{b-c}$, etc., $2t_{b-c}$, $4t_{b-c}$, $6t_{b-c}$, etc., and a series of negative unit voltages impressed at t equals $-t_{b-c}$, $-3t_{b-c}$, $-5t_{b-c}$, etc., t_{b-c}, $3t_{b-c}$, $5t_{b-c}$, etc. The associated transient functions will form the periodic response to the square wave. It is evident that the apparent time delay plus an integral multiple of the period of the square wave is determinable from (11). This information together with the fact that the intercept on the phase-delay characteristic in Fig. 9 is approximately equal to the effective delay will define the delay explicitly. It is conceivable that this procedure may fail in special cases.

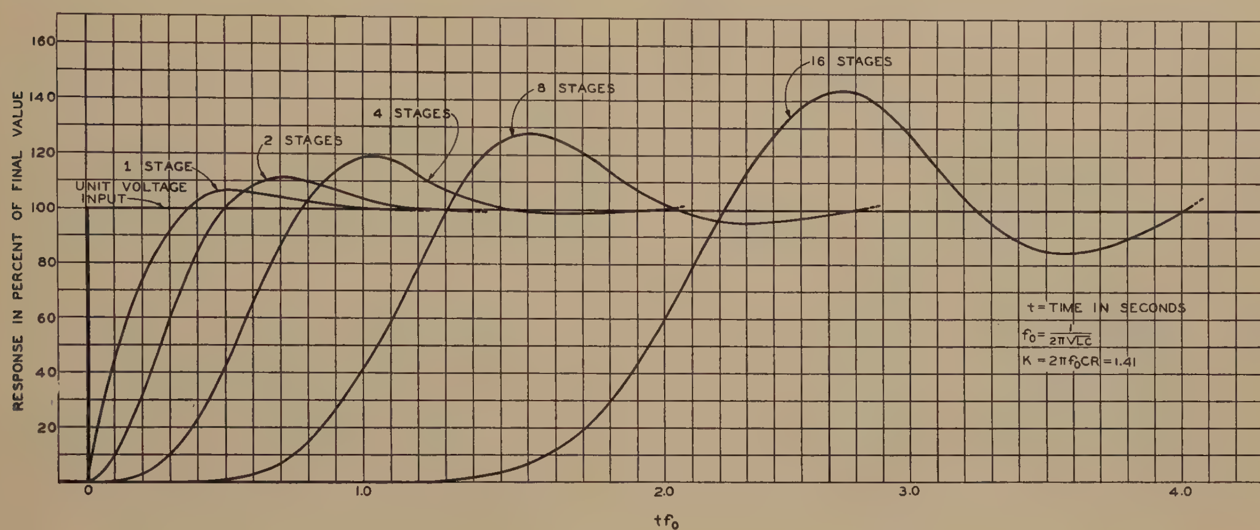


Fig. 10—Response of multistage amplifiers to a unit voltage.

The character of the responses of the various 16-stage amplifiers may be compared directly on the basis of equal low-frequency gain as a result of the choice of independent variable tf_0/K; similarly in the cases of 32- and 64-stage amplifiers. The essential character of the response is controlled by the parameters K and f_0 which may be specified independently. K determines the magnitude of the damped oscillation and f_0 determines the steepness of the wave front.

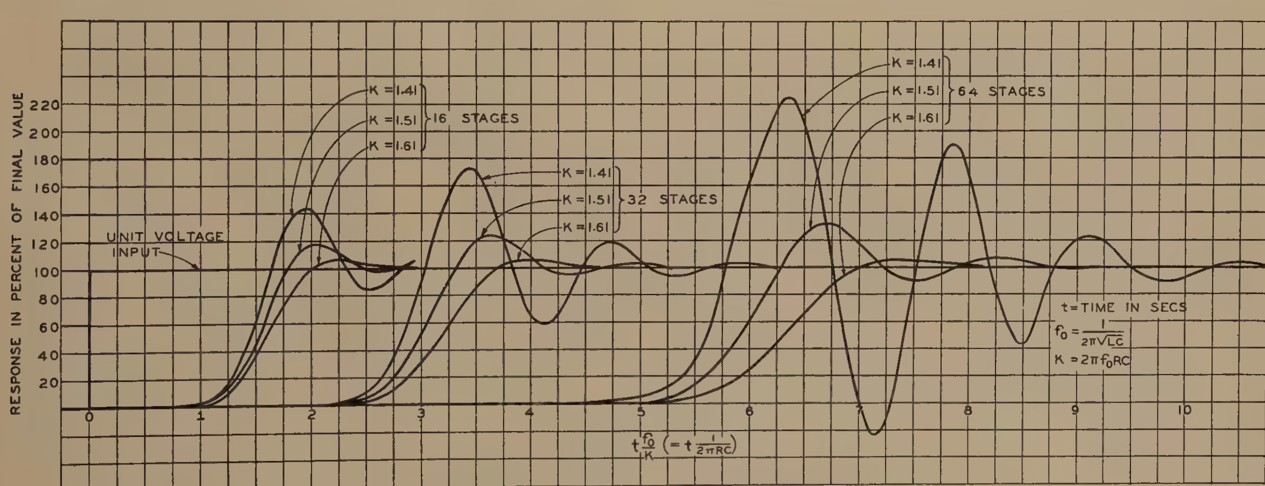


Fig. 11—Response of multistage amplifiers to a unit voltage.

If the cathode-ray beam of a receiving tube is modulated by the response of 32 stages, $K=1.41$, a

series of alternate light and dark striations will be distinctly visible following the scanning of a vertical black-to-white junction, as a result of the damped oscillation in the signal. A definite standard of tolerable damped oscillation in the response of video-frequency amplifiers must treat (1) amplitude, (2) frequency, and (3) rate of decay. To set up a standard is not the purpose of this paper. However, observation of television pictures transmitted by multistage video-frequency amplifiers with $K=1.41$ has led to a general rejection of this value. Figs. 10 and 11 ably support this rejection. We believe that the K factor should lie between 1.51 and 1.61.

The horizontal resolution of a television picture is substantially proportional to the slope of the wave front of the over-all response to a unit voltage. If a slope is specified, the resonant frequency f_0 may be determined by reference to the scale of abscissas in Figs. 10 and 11. For example, a 32-stage amplifier $K=1.51$ has an effective linear rise from 0 to 100 per cent response within about 0.8 unit on the axis of abscissas. Let this correspond arbitrarily to 0.16×10^{-6} second. Then

$$0.8 = t\frac{f_0}{K} = \frac{0.16 \times 10^{-6} \times f_0}{1.51}$$

$$f_0 = 7.5 \times 10^6 \text{ cycles.}$$

Experimental Determination of the Transient Response

The mathematical determination of the transient response may be obviated in the case of existing amplifiers when a generator of a square-wave form and a suitable oscillograph are available. Thus the fidelity of a video-frequency amplifier can be determined directly from an oscillographic observation of the response to a square wave of suitable period by noting the steepness of the wave front and the character of the damped oscillation. Clearly, the analytical method should give way to the experimental method whenever possible in order to avoid the labor involved in finding amplitude and phase-delay characteristics and the subsequent series solution of the transient response.

If the amplitude and phase characteristics are required for the design of correcting networks, the experimentally determined square-wave response may be analyzed graphically by the well-known methods of harmonic analysis.

Conclusions

The transient nature of the signals which television amplifiers are required to amplify suggests that the most logical and relevant criterion of the fidelity is the response of the amplifier to a Heaviside unit voltage. The survival of the older criterion based on the steady-state characteristics of amplitude response and phase delay is caused probably by the large accumulation of knowledge of electric filters based also on these steady-state characteristics.

We have shown that the part of the response to a unit voltage that is governed by the high-frequency amplitude and phase-delay characteristics of amplifiers may be approximated by the steady-state response to a square wave. Simplicity and rapidity of numerical calculation are the outstanding advantages of the steady-state series formulation over the method of operational calculus and the Fourier integral formulation.

The series is formed by finding the steady-state response to a square wave of voltage having a half period that is longer than the time interval required for the response to attain a steady value starting at the time of the first appreciable response. Convergence of the series is most rapid when the shortest period satisfying the above condition is used. Trial calculation will reveal the error in judgment when the period is too short.

A detailed analysis of the compensated resistance-coupled amplifier yields the following conclusions: (1) The wave-shape distortion of a unit voltage is accumulative as the number of stages is increased. (2) The value of the damping constant K should lie between 1.51 and 1.61 in most cases. (3) The resonant frequency f_0 determines the slope of the wave front of the transient response.

We propose that the oscillographic response of video-frequency amplifiers and the associated equipment to a square wave be considered as a part of performance tests of future television systems.

Characteristics of the Ionosphere at Washington, D.C., February, 1939*

T. R. GILLILAND†, ASSOCIATE MEMBER, I. R. E., S. S. KIRBY†, ASSOCIATE MEMBER, I. R. E., AND N. SMITH†, NONMEMBER, I. R. E.

DATA on the critical frequencies and virtual heights of the ionosphere layers during February are given in Fig. 1. Fig. 2. gives the monthly average values of the maximum frequencies which could be used for radio sky-wave communication by way of the regular layers. Fig. 3 gives the distribution of the hourly values of F- and F_2-layer critical frequencies and maximum usable frequencies about the average for the month. Fig. 4 gives the expected values of the maximum usable frequencies

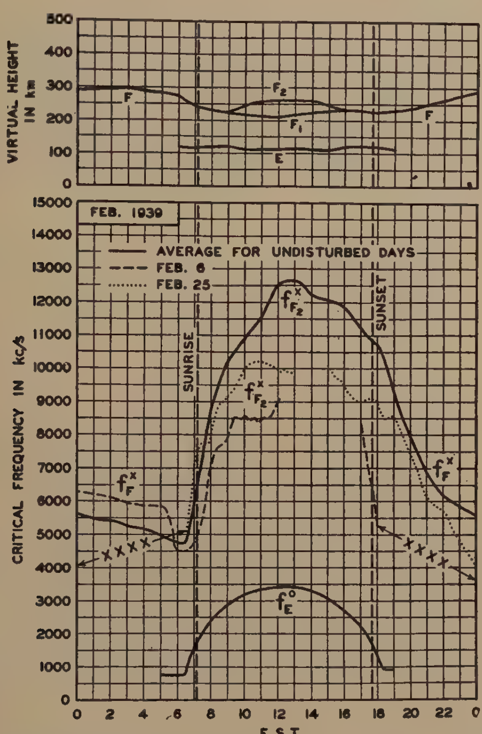


Fig. 1—Virtual heights and critical frequencies of the ionosphere layers, February, 1939. The solid-line graph is the undisturbed average for February, 1939. The dashed-line and dotted-line graphs are for the ionosphere storm days of February 6 and 25, respectively. The crosses represent the times on these days when the critical frequencies were too poorly defined to measure.

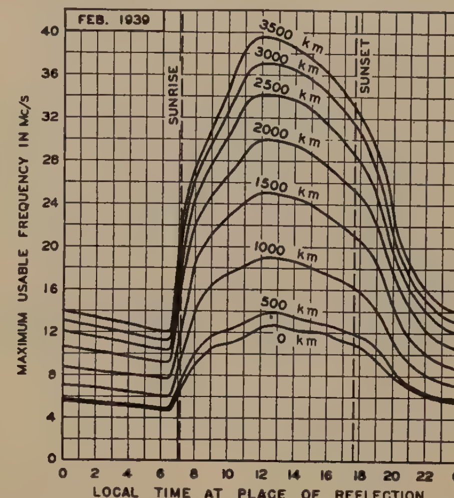


Fig. 2—Maximum usable frequencies for sky-wave radio transmission; averages for February, 1939, for undisturbed days, for dependable transmission by the regular F and F_2 layers.

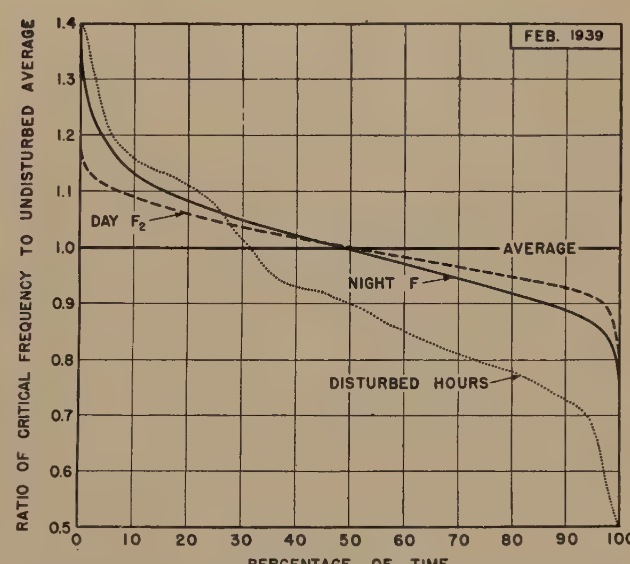


Fig. 3—Distribution of F and F_2 critical frequencies and maximum usable frequencies about monthly average. Abscissas show percentage of time for which the ratio of the critical frequency to the undisturbed average exceeded the values given by the ordinates. The graphs give data as follows: solid line, 307 hours of observations on undisturbed nights between 1800 and 0600 E.S.T.; dashed line, 105 hours on undisturbed days between 0700 and 1700 E.S.T.; dotted line 64 of the 88 disturbed hours listed in Table I.

* Decimal classification: R113.61. Original manuscript received by the Institute, March 11, 1939. These reports have appeared monthly in the PROCEEDINGS starting in vol. 25, September, (1937). See also vol. 25, pp. 823–840, July, (1937). Publication approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce.

† National Bureau of Standards, Washington, D. C.

for transmission by way of the regular layers, average for May, 1939. The ionosphere storms and sudden ionosphere disturbances are listed in Tables I and II, respectively.

The severe ionosphere storm beginning on February 24 at about 1200 E.S.T. was marked by an ini-

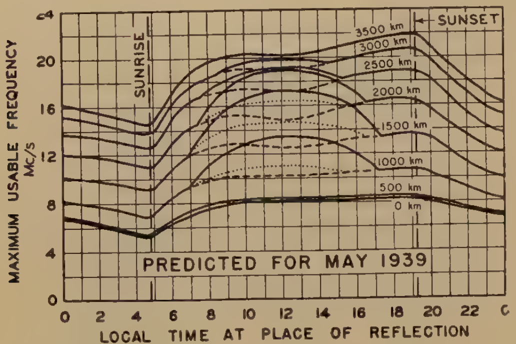


Fig. 4—Predicted maximum usable frequencies for sky-wave radio transmission May, 1939. Solid-line graphs represent average values for undisturbed days for dependable transmission by the regular ionosphere layers. The values shown will be considerably exceeded during occasional irregular periods by reflections from clouds of sporadic-E layer. For distances of 1000, 1500, and 2000 kilometers the dotted and dashed portions of the graph represent predicted maximum usable frequencies for F_1- and F_2-layer transmission, respectively, when these are less than those determined by the E layer. For distances of 2500 and 3000 kilometers the dashed line represents predicted maximum usable frequencies for F_2-layer transmission when these are less than those determined by the F_1 layer.

tial increase in F_2-layer ionization, followed by a severe turbulence similar to that reported for the storm of May 11, 1938. The turbulence began at about 1620 E.S.T. on February 24 and was accompanied by poorly defined F-layer critical frequencies all night.

Sporadic-E-layer reflections were observed at 6 megacycles or above about 1 per cent of the time.

The effect of ionosphere storms on transmissions at broadcast frequencies was described briefly in the report of this series for May, 1938. Data obtained subsequently, and especially during February, 1939, confirm and extend the conclusions given there. During the initial stages of severe ionosphere storms in the daytime the intensities of sky waves at broadcast frequencies, reflected from a low (D) layer, rose to about three times normal. During storms of moderate or severe intensity at night, when the waves were reflected by the E layer, the intensities fell to 0.3 to 0.02 of the normal values (usually to

TABLE I

IONOSPHERE STORMS (APPROXIMATELY IN ORDER OF SEVERITY)

Date and hour E.S.T.	h_F before sunrise (km)	Minimum f_F^x before sunrise (kc)	Noon $f_{F_2}^x$ (kc)	Magnetic character[1]		Ionosphere character[2]
				00–12 G.M.T.	12–24 G.M.T.	
Feb.						
24 (after 1200)	—	—	—	0.9	1.9	1.8
25	292	3800	10,000	1.9	1.1	0.9
26 (until 0800)	312	3600	—	0.4	0.2	0.5
5 (after 1900)	—	—	—	0.1	0.7	0.3
6	284	4500	9,000	1.2	1.4	1.2
7 (until 0500)	298	4500	—	0.8	0.4	0.3
1 (after 1600)	—	—	—	0.2	0.8	0.3
For comparison: Average for undisturbed days	288	4769	12,500	0.3	0.4	0.0

[1] American magnetic character figure, based on observations of seven observatories.
[2] An estimate of the severity of the ionosphere storm at Washington on an arbitrary scale of 0 to 2, the character 2 representing the most severe disturbance.

about 0.1 normal). The weak night sky-wave intensities persisted for four or five nights after other indications of the storms had passed. Since there was considerable time between storms in February there were periods when the night sky-wave intensities consistently had values which were normal during the sunspot minimum. It appears that weak average

TABLE II

SUDDEN IONOSPHERE DISTURBANCES

Date 1939	G.M.T.		Location of transmitter	Relative intensity at minimum[1]
	Beginning of fade-out	End		
Feb. 16	1854	1906	Ohio, Ontario, D. C.	0.05

[1] Ratio of received field intensity during fade-out to average field intensity before and after; for station W8XAL, 6060 kilocycles, 650 kilometers distant.

night sky-wave intensities of broadcast transmissions observed during recent years have been due largely to the greater prevalence of ionosphere storms rather than to other phenomena of the sunspot maximum.

Some recent papers have cast doubt on the validity of the calculations of maximum usable frequencies,[1,2] as shown in Fig. 2, by suggesting that the Lorentz polarization term should be taken into account. The continuous systematic high-frequency field-intensity recording of oblique-incidence transmissions by the National Bureau of Standards indicates that a correction for the polarization term should not be applied to such transmissions.

[1] H. G. Booker and L. V. Berkner, *Nature*, vol. 141, p. 562, (1938).
[2] D. R. Goddard, "Observations on sky-wave transmission on frequencies above 40 megacycles," PROC. I.R.E., vol. 27, pp. 12–16; January, (1939).

TREASURE ISLAND

In San Francisco Bay, dominated by its 400-foot Sun Tower, stands Treasure Island on which the San Francisco World's Fair is being held. Berkeley and Alameda can be seen across the bay. From June 27 to 30, a national convention of the Institute will be held in San Francisco. The complete program will appear in the June issue of the Proceedings. Those interested in presenting papers should address Professor F. E. Terman at Stanford University, San Francisco.

Institute News and Radio Notes

Board of Directors

The regular meeting of the Board of Directors was held in the Institute office on Wednesday, March 1, 1939. Those present were R. A. Heising, president; Melville Eastham, treasurer; H. H. Beverage, Ralph Bown, F. W. Cunningham, Alfred N. Goldsmith, Virgil M. Graham, Alan Hazeltine, L. C. F. Horle, C. M. Jansky, Jr., F. B. Llewellyn, Haraden Pratt, B. J. Thompson, H. M. Turner, A. F. Van Dyck, and H. P. Westman, secretary.

Thirty-three Associates, one Junior, and sixteen Students were admitted to membership.

As a result of his nomination by the Institute, Haraden Pratt was elected to serve as a member of the Board of Directors of the American Standards Association for a three-year term starting January 1, 1939.

The report of the Tellers Committee on the ballots cast in the vote on amending the Institute Constitution was accepted.

Thirty-one per cent of the voting membership cast ballots, which is greater than the minimum of twenty per cent required for a successful Constitutional vote. Of the ballots cast, eighty-five per cent were in favor of all amendments proposed, two per cent were against any changes in the Constitution, and thirteen per cent indicated objections to one or more specific sections of the proposed amendments.

As the Constitution requires that amendments be adopted if seventy-five per cent of the votes cast are in favor of the adoption, and as eighty-five per cent of the votes cast were favorable, the proposed amendments were all approved.

The revised Constitution was adopted as of March 1, 1939, and becomes effective on March 31, 1939.

Because all voting members of the Institute received a copy of the proposed amendments with their ballots, it was agreed that a new printing would not be made until the Bylaws have been amended by the Board of Directors to become consistent with the new Constitution.

Institute representatives on a committee in charge of the revision of certain sections of the National Electrical Code reported on the undesirability of the inclusion in that Code of articles permitting the installation of conductors called "Covered Neutral Cables" and "Uninsulated Neutral Conductors." It is evident that the adoption of these types of wiring in homes will result in radio noise being introduced into receivers in a degree which will seriously affect their value to the user.

The committee was empowered to take action against the adoption of these new sections.

A report of a special committee considering modification of the New York State law for the registration of professional engineers was considered. The committee was continued in force and directed to supply additional data which are felt necessary before a specific program can be adopted for further action.

I.R.E.—U. R. S. I. Meeting

The annual joint meeting of the Institute of Radio Engineers and the American Section of the International Scientific Radio Union will be held in Washington, D. C., on Friday and Saturday, April 28 and 29. The Friday meeting will be held at the National Academy of Sciences, 2101 Constitution Avenue, from 10:00 A.M. to approximately 5:00 P.M. The Saturday meeting will probably be held at the same place, but from 9:00 A.M. to approximately 11:00 A.M. The Ionosphere Conference arranged by the Department of Terrestrial Magnetism, Carnegie Institution of Washington, will be held at its building, 5241 Broad Branch Road, N.W., beginning at 11:30 A.M. on Saturday. All times are Eastern Standard Time.

The final program with abstracts will be available for distribution about April 15. Correspondence should be addressed to S. S. Kirby, National Bureau of Standards, Washington, D. C. The papers will be presented at the meeting in approximately the order listed in the tentative program below.

Tentative Program, April 28 and 29, 1939

"Further investigations of a possible lunar effect on radio field intensities," by H. T. Stetson, Massachusetts Institute of Technology.
"The impetus which aviation has given to the application of ultra-high frequencies," by W. E. Jackson, Civil Aeronautics Authority.
"Trans-Atlantic reception of London television signals," by D. R. Goddard, R.C.A. Communications, Inc.
"An experimental investigation of the characteristics of certain types of noise," by K. G. Jansky, Bell Telephone Laboratories.
"Field-strength survey, 52.75 megacycles from Empire State Building," by G. S. Wickizer, R.C.A. Communications.
"New dielectric electric cable," by Professor Brillouin, University of Paris.
"Comparison of long-distance broadcast transmissions over different paths," by S. S. Kirby and F. R. Gracely, National Bureau of Standards.
"A method for measuring the gain of transmitting antennas and certain phenomena affecting transmission of high-frequency signals," by A. Alford, Mackay Radio and Telegraph Company.
"Cathode-ray direction finder," by J. T. Henderson, National Research Council. (Ottawa, Canada.)
"Cathode-ray direction finding of atmospherics," by J. T. Henderson, National Research Council. (Ottawa, Canada.)
"An inductive-output high-frequency power amplifier," by A. V. Haeff, R.C.A. Manufacturing Company. (Harrison, N. J.)
"Tuned-grid—tuned-plate oscillator," by I. E. Mouromtseff, Westinghouse Electric and Manufacturing Company.
"Ionosphere disturbances, 1937–1938," by J. H. Dellinger, National Bureau of Standards.
"Exploration of the earth's outer atmosphere," by L. V. Berkner, Carnegie Institution of Washington.
"Comparison of simultaneous ionosphere observations at Washington, D. C., and Deal, N. J.," by J. P. Schafer and W. M. Goodall, Bell Telephone Laboratories.
"The prediction of ionosphere characteristics and maximum usable frequencies," by N. Smith and A. S. Taylor, National Bureau of Standards.
"The reception of radio echoes from distant ionospheric irregularities," by J. A. Pierce and H. R. Mimno, Cruft Laboratory, Harvard University.
"The measurement of ionosphere reflections at nonvertical incidence," by O. Rydbeck, Cruft Laboratory, Harvard University.

Sections

Atlanta

P. H. Collins, who was one of those present when Marconi received the first wirless message transmitted across the Atlantic Ocean, was introduced, as a special guest, by the chairman. He gave a description of the event and mentioned a number of incidents which occurred during the experiment.

Ben Akerman, chief engineer of WGST in Atlanta, then presented a paper on "Modern Broadcast Studios and Associated Equipment." The WGST studios were installed in an existing building which presented many problems not met when special structures are designed for the purpose. In discussing the acoustic design of the rooms details of the slanting nonparallel walls and windows and the silencing of the air-conditioning installation were emphasized.

The control system was described and its flexibility stressed. The various amplifiers and their uses were covered. There was then described and demonstrated a new volume-level indicator of the type recently developed for broadcast service.

The paper was closed with a demonstration in which an old Edison record and a new vertically cut record were reproduced through high-quality amplifiers to demonstrate the progress which has been made in program recording.

At the close of the paper an inspection tour of the plant was made.

December 15, 1938—C. F. Daugherty, chairman, presiding.

The annual meeting of the section resulted in the election of Ben Akerman, chief engineer of WGST, to serve as chairman; G. S. Turner, inspector-in-charge, Federal Communications Commission, as vice chairman; and J. G. Preston continuing to serve as secretary-treasurer.

Tracy Barnes, service engineer of the Brown Distributing Company, presented a paper on "Low-Power Radio-Frequency Control Devices."

After explaining the use of an induction field for control purposes and the factors affecting the choice of frequencies to be used in such a system, the speaker discussed in detail the Philco "mystery con trol." The remote-control oscillator was described and a partially dismantled unit displayed.

The pickup loop and control amplifier used in the receiver were discussed. The thyratron control tube and "stepper assembly" which translates the impulses received into receiver-control actions were described. One of these switches was available for inspection. The over-all performance characteristics of the control system were outlined.

The speaker then described two Philco record players which employ radiated fields for coupling to the receiver which is used for amplifying and reproducing purposes.

The Federal Communications Commission has established regulations on the use of these low-power radio-frequency radiating devices. These were read and a discussion of them was given by G. S. Turner of the Commissions' staff.

January 19, 1939—C. F. Daugherty, chairman, presiding.

Buffalo-Niagara

"Broadcast Facsimile" was discussed by H. J. Lavery, research engineer of the RCA Manufacturing Company (Camden).

The apparatus described draws 125 lines per inch and employs a light spot in the scanner approximately 0.003 by 0.008 inch and a light flux of 0.06 lumen. The reflected light is converted in a phototube into an electric current which is used to modulate the radio transmitter. The modulation is arranged to give highest amplitude for the darkest area scanned.

In the receiver, the signal actuates a bar which applies pressure to carbon paper in contact with the record paper. The area of the bar in contact with the paper is approximately the same as the size of the scanning spot at the transmitter. The pressure is adjusted so that the strongest modulated signal gives a spot of maximum pressure on the bar.

February 8, 1939—H. C. Tittle, chairman, presiding.

Chicago

"General Properties of Mixer and Converter Tubes" was the subject of a paper by Curtis Hammond, circuit engineer for the Ken-Rad Tube and Lamp Corporation.

The characteristics of various types of mixer and composite converter tubes now in general use were described and compared. Emphasis was placed on those little-understood properties such as conductance loading as exhibited by signal input grids, space-charge capacitive coupling between various elements of composite converters, and normal conversion-gain variations. It was pointed out that the input conductance of signal grids may be either positive or negative and factors affecting it were analyzed.

January 20, 1939—V. J. Andrew, chairman, presiding.

Cincinnati

Harvey Fletcher, physical research director of Bell Telephone Laboratories, presented a paper on "Auditory Patterns" before a joint meeting of the local sections of the Institute, the American Institute of Electrical Engineers, Sigma Xi, and the Engineers Club of Dayton.

The construction and operation of the human ear were described. The perception of sound at various frequencies and power levels was demonstrated. Animated pictures, the voice mirror, and a large amount of other acoustical apparatus were demonstrated.

January 13, 1939—J. A. Noertker, chairman of the American Institute of Electrical Engineers Section, presiding.

E. F. Nuezel, vice president of the Technical and Scientific Societies Council of Cincinnati, presided at the annual meeting of the Council which was attended by members of all technical and scientific societies of the city. J. D. Stewart, Mayor of Cincinnati, introduced the speaker, H. H. Clegg, assistant director of the Federal Bureau of Investigation of the U. S. Department of Justice. A paper on "Scientific Methods of Crime Detection" was presented.

The problem is to control approximately 5,000,000 criminals whose activities cost about $15,000,000,000 yearly and

who are responsible for a million and a half major crimes annually. About thirty per cent of all criminals arrested have previous records and about eighteen per cent are younger than voting age.

Descriptions were then given of the fingerprint files, ultraviolet ray and fluoroscope equipment, and other useful aids such as moulage casts, files of tire treads, and files of water marks of the types used on writing paper. The paper was closed with descriptions of a number of interesting cases solved by the Bureau.

February 24, 1939.

Cleveland

New officers were elected as this was the annual meeting. S. E. Leonard, chief engineer of WTAM, was named chairman; R. L. Kline, of Winteradio, Inc., was designated vice chairman; and H. C. Williams, of the Ohio Bell Telephone Company, was elected secretary-treasurer.

Two papers were presented. The first by E. L. Gove, technical supervisor of WHK, was entitled "Finch Facsimile Transmission and Equipment," and the second, by R. A. Fox, of WHK, gave the "Results of a High-frequency Survey."

Mr. Gove contrasted point-to-point facsimile systems with a broadcast service. The necessity of simplifying the broadcast receiver to operate with the pressing of a button was stressed. Recent developments in ultra-high-frequency systems now provide satisfactory automatic volume control and sufficient stability of tuning to permit this type of operation.

An historical outline of methods used in various facsimile systems was given and the Finch system using a dry-paper recorder and start-stop synchronization was described in detail. The advantages of this synchronization method where areas served by more than one power system are involved were discussed.

The Federal Communications Commission's requirements for the launching of such a new public service were outlined. Receivers must be placed in the field on a trial basis and not more than ten per cent may be in the hands of technically trained persons. Quantitative data giving coverage of the transmitter must be presented and to obtain this, a survey of the Cleveland area was made under the direction of R. A. Fox.

Mr. Fox presented data on the survey of the transmission from W8XE on a frequency of 38.3 megacycles. A half-wave J-type antenna mounted on top of the flagpole of Cleveland's Terminal Tower was fed through a coaxial line from the 15-watt transmitter located on the 44th floor of the building. The antenna was 850 feet above Lake Erie and 776 feet from the sidewalk.

The receiver, employing a quarter-wave vertical antenna, was mounted in a mobile unit and 354 spot measurements made to distances up to about 15 miles. Measurements were spotted on a map and contour lines drawn for 0.5-millivolt steps.

A series of measurements were also taken over water. One such series showed the signal fading at 35 miles which was the horizon with respect to the transmitting antenna. Beyond this distance, the signal increased until at the Perry Monument, which is 58.5 miles away, the intensity was the same as at 17 miles. Refraction caused by humidity variation was suggested as a partial explanation of this.

JESSE MARSDEN

Jesse Marsden (A'18, M'25) who has served as chief engineer of the International Resistance Company for several years, has recently been named vice president of that organization. He continues in his capacity as chief engineer.

It was pointed out that in reception, interference caused by automobiles appeared to be the most important factor. In areas with congested traffic, 3 to 5 millivolts per meter were required while in suburban areas with low traffic 0.5 millivolt was sufficient for satisfactory service. The contour map and various field-strength charts made with a recording device were shown.

A demonstration of facsimile broadcasting was given using receivers manufactured by the Crosley Radio Corporation. Receivers for both two-column and four-column pages were demonstrated. Monitoring receivers permitted rapid comparison between the original, copy from a receiver fed directly from the scanning equipment, and copy from a receiver actuated by the transmitter at a field strength equivalent to a distance of about 12 miles.

January 26, 1939—G. H. Grostick, vice chairman, presiding.

Connecticut Valley

"Principles and Methods in Television Laboratory Technique" was the subject of a paper by S. W. Seeley of the RCA License Laboratory. It contained a description of various methods and measurements useful in television laboratory work and not normally encountered in other radio practices. A description was given of several of the major elements of television receivers together with the desired operating characteristics. Methods of determining these performance characteristics were outlined. A demonstration was given of some of the measuring instruments which had been found useful in this work.

June 23, 1938—D. E. Noble, chairman, presiding.

Detroit

B. R. Curtis, research physicist at the University of Michigan, presented a talk on the work on the cyclotron at the University of Michigan. Dr. Curtis described first the fundamental principles of the cyclotron which has been found useful in the fields of chemistry, physics, medicine, and metallurgy. He then described briefly the specific uses to which this particular cyclotron has been applied.

A list of various substances which can be made radioactive by electronic bombardment in the cyclotron was given and possible uses of these discussed.

The problems encountered in coupling the radio-frequency oscillator to the cyclotron were explained. The tubes used in the oscillator were homemade and constructed to permit dismantling to replace or modify elements. A sample tube was on display.

Methods of sealing for vacuum in the cyclotron were described.

This was the annual meeting of the section and L. C. Smeby of WXYZ was named chairman; H. C. Seielstad of the Department of Commerce was designated vice chairman; and R. J. Schaefer of the Briggs Manufacturing Company, secretary-treasurer.

December 16, 1938—E. H. Lee, chairman, presiding.

"Applications of Standard Relays in Electronics" was the subject of a paper by R. H. Herrick, consulting engineer for the Automatic Electric Company.

The history of the development of relays was first presented.

Fast-operating relays were first discussed and design and manufacturing problems were described. Such relays may operate and release in time intervals as short as five milliseconds.

To retard the speed of operation, a low-resistance copper ring is placed at the armature end of the core. The delay is a function of the length of the copper ring. The ring operates as a short-circuited turn and a current is induced in it whenever the flux through the core is changed.

For telephone-dialing circuits, a relay is required which must operate rapidly but release slowly. This is accomplished by placing a copper ring or a slug at the end of the core opposite the armature.

There is sufficient flux leakage along the length of the core to permit a fairly rapid increase in flux at the armature end on the operating cycle and the armature moves with relatively small delay. When the operating voltage is removed the induced currents in the slug tend to maintain the flux in the core and the release cycle is slower.

Relays used with electronic tubes were described. Major factors such as the number of ampere turns required for stable operation, the non-operate and operate current limits, and the effect of the coil inductance on the operate and release times.

A demonstration was presented of the operation of various types of relays.

January 20, 1939—L. C. Smeby, chairman, presiding.

Emporium

W. P. Mueller of the tube-application department of the Hygrade Sylvania Corporation, presented a discussion of the various component parts of a television receiver. As a basis for the discussion he used the RMA television-signal standard. Special emphasis was placed upon the requirements of various types of circuits used for test equipment.

February 21, 1939—Ray McClintock, chairman, presiding.

Los Angeles

"Microphones for Sound Recording" were discussed by F. L. Hopper, research engineer for Electrical Research Products, Inc. It comprised the history of the development of microphones used in sound-recording work with the advantages and limitations of each type being outlined. A large number of microphones were on display to illustrate these developments.

A second paper on "Velocity Variations in Sound-Picture Mechanics," was presented by R. R. Scoville of the same organization. In it, he discussed and illustrated the effects of velocity variations and methods used to surmount them in recording systems. Apparatus was demonstrated with artificially imposed velocity variations in both percentage of modulation and percentage of frequency variation. It was shown that under certain conditions minute variations become very apparent. In properly designed equipment these variations may be caused by poor adjustment or wear.

This was the annual meeting and F. G. Albin, of United Artists Studios, was elected chairman; A. C. Packard, of Columbia Broadcasting System, was named vice chairman; and M. T. Smith, of the General Radio Company, was designated secretary-treasurer.

December 20, 1938—R. O. Brooke, chairman, presiding.

L. C. Howard, electrical engineer of the Inca Manufacturing Company, presented a paper on "Recent Developments in Audio-Frequency Transformer Design." It covered many types of transformers used in audio-frequency low-power amplifiers. Emphasis was placed on output transformers, class B amplifier transformers, and inpute transformers for class A operation. Design formulas were presented and their use in the development of transformers demonstrated.

It was pointed out that developments during the last few years of new alloys suitable for cores and shielded cases have been of great significance in transformer design. A 90-decibel reduction in external hum may be obtained by using several alternate layers of copper and high-permeability shielding.

Harry Kimball, sound engineer for Metro-Goldwyn-Mayer Studios, then presented a paper on "Electrical Filters and Equalizers." He discussed briefly the design of the usual types of filters used in recording work by the motion-picture industry, giving details of the design of equalizers to have predetermined frequency characteristics. Data were presented from which it is possible to design an equalizer when only two points in the attenuation characteristic and the characteristic impedance of the line are known.

January 17, 1939—F. G. Albin, chairman, presiding.

Montreal

"The Early Microphone and Recent Research" was the subject of a paper by F. S. Goucher of Bell Telephone Laboratories. In it Dr. Goucher traced the evolution of the present telephone transmitter from its earliest beginnings in the crude apparatus of Bell and Hughes, which did not use carbon contact, to the present types. Each of the early models was demonstrated by speaking into them and playing back the speech as recorded on a steel tape. The extreme sensitiveness of carbon contacts to pressure was strikingly demonstrated. A three-foot piece of rail, supported on each end, had a single carbon contact arranged between its lower flange and a fixed base. A battery caused a steady current to flow through a milliammeter. This current could be seen to vary appreciably when one breathed on top of the rail, the deformation being caused by the unequal expansion of the rail due to temperature differences. This movement was stated to be of the order of 100 molecules thickness.

J. R. Haynes assisted in the demonstrations.

February 9, 1939—S. Sillitoe, chairman, presiding.

New Orleans

Dana Pratt of the RCA broadcast engineering department (Camden), presented a paper on "High-Efficiency, High-Power Amplifiers."

After a general description of high-efficiency amplifiers, the author discussed the RCA type 50D transmitter specifically. As the meeting was held in the transmitter room of Station WWL, the actual pieces of equipment could be pointed out during the discussion.

December 9, 1938—G. H. Peirce, chairman, presiding.

New York

"Wave-Guide Radiators and Electromagnetic Horns" was the subject of a demonstration-lecture given by G. C. Southworth and A. P. King of the Bell Telephone Laboratories.

This was a continuation of a similar lecture given a year previously on the use of wave guides as transmission lines. A series of experiments showed the characteristics of wave guides employed as radiators. The electromagnetic horn was considered a special form of such a radiator. These horns may be used either singly or in arrays, to produce by directivity effective power ratios of several hundreds or possibly thousands. The directional characteristics of such horns were demonstrated. Most of the demonstrations employed frequencies of about 3000 megacycles corresponding to wavelengths shorter than ten centimeters.

February 1, 1939—President Heising, presiding.

Philadelphia

Two papers were presented. The first was "A New Armstrong Frequency-Modulation Receiver," by G. W. Fyler of the General Electric Company (Bridgeport), and the second on "Frequency Modulation Field Tests in the Schenectady-Albany Area," by I. R. Weir of the General Electric Company (Schenectady). These papers were summarized in the report of the January 19 meeting of the Connecticut Valley Section which appears in the March PROCEEDINGS.

February 21, 1939—H. J. Schrader, chairman, presiding.

Pittsburgh

"Ears and Eyes" was the subject of a paper by R. P. Griffith of the Bell Telephone Company of Pennsylvania.

The construction of the ear was described. The frequencies and volume range over which the ear operated were outlined. It was pointed out that at 230 decibels above the minimum sound perceptible to the ear, the sound pressure would be approximately 4000 pounds per square inch and would result in death. The sensitivity of the average person's hearing decreases a fraction of a decibel each year.

The eye was similarly considered and a detailed description of its structure presented. Assuming that the maximum

sensitivity of the eye permitted the light of a candle at a distance of six miles to be perceptible and calling that zero level, the maximum stimulus was indicated as being 110 decibels above that zero level. The sun was rated at 130 decibels on the same scale. The 200-inch telescope was computed to give a gain of 70 decibels in light intensity.

November 15, 1939—W. P. Place, chairman, presiding.

Homer Davies, of the Washington Institute of Technology, presented a paper on "Radio Landing Beams." It included a brief but detailed history of the work in this field by the National Bureau of Standards up until the time the various airlines and other interested organizations became active in the field.

R. O. Smith, of the Pennsylvania Central Airlines, then spoke on "Radio in Aviation." In it he described the troubles of the early days in obtaining satisfactory communication with planes in flight and the development of the present-day two-way systems. It was pointed out that normal operation requires notifying the Civil Aeronautics Authority in Washington whenever a plane is a minute and a half overdue in contacting the ground radio station. Passenger planes flying over water must contact a ground station or air field at least every five minutes.

December 20, 1938—W. P. Place, chairman, presiding.

This meeting was held jointly with the Physical Society of Pittsburgh and presided over by G. R. Greenslade, chairman of that organization.

A paper on "The Measurement of Elastic Constants of Single Crystals by Means of Piezoelectric Oscillators," was presented by Sidney Siegel, a Fellow at the Westinghouse Electric and Manufacturing Company research laboratory. In it, Dr. Siegel described his method of arriving at Young's modulus of elasticity of single crystals of elements and compounds by means of piezoelectric oscillators generating supersonic waves whose lengths are comparable to the size of the crystals under test. Former methods entailed use of considerably shorter wavelength vibrations.

There were then described methods of crystallizing metallic sodium in capillary tubes in vacuo and in obtaining resonant-frequency curves at various temperatures and at zero pressure.

Numerous demonstrations of the elastic constants of crystals have been made and a future research program of this nature was outlined.

February 2, 1939.

"Characteristics of Hearing" were discussed by S. F. Lyberger, chief engineer of E. A. Myers Company. A description of the mechanism of the auditory system was first presented. The difference between the threshold of feeling and of hearing was explained. In a survey of about seventeen thousand ears, it was found that sixty-five per cent were normal; fourteen per cent showed a twenty-decibel loss; ten per cent, a fifty-decibel loss; eight per cent, a sixty-five decibel loss; and four per cent a loss between eighty-five and ninety decibels. Those showing losses of fifty decibels were considered to be poor.

Hearing aids should be lightweight, not exceeding one pound, provide sufficient amplification over the frequency range in which the hearing is defective, and provide low cost of operation, usually a quarter of a cent per hour or less. Complete units including the battery weighing as low as seven and one-half ounces were displayed.

Vacuum-tube-type amplifiers give less distortion than the carbon varieties and much fundamental work on portable units of this type is in progress. A set weighing two pounds has been produced.

Bone-conduction instruments require more power to operate and may give truer tonal quality than others. Because of the various types of impairment, it is an engineering problem to fit a partially deaf person and give intelligent audition.

R. T. Gabler, of Carnegie Institute of Technology, presented a paper on "Constant-Resistance Networks and Their Derivation." He discussed the design of equalizers in sound systems to compensate for various distortions of an electrical nature. Correction may be made of other types of distortion which may affect the characteristics of the system. Constant-resistance-type equalizers such as ladder, lattice, and bridge-T structures were described. The ladder type is used most. Various designs and formulas were given. The characteristic curve of an amplifying system before and after corrective networks had been installed were displayed.

February 21, 1939—W. P. Place, chairman, presiding.

Portland

J. W. Wallace, chief engineer of the Puget Sound Broadcasting Company, presented a paper on "Relay Broadcasting and Special Events."

February 9, 1939—H. C. Singleton, chairman, presiding.

H. H. Willis, chief research engineer of the Speery Gyroscope Company, spoke on "Developments in Aerial Navigation."

Dr. Willis outlined the numerous developments in which his company has been interested in the field of aerial navigation, particularly where radio methods and equipment are used. Instrumentation was discussed from the viewpoint of increased safety in air transportation and included descriptions of regular flight instruments, the automatic pilot, the Speery-RCA automatic radio compass, and the flight ray. Mention was made of the Klystrom and Rhumbatron developments at Stanford University and their possible application to the problem of blind landing.

March 3, 1939—H. C. Singleton, chairman, presiding.

Rochester

At a joint meeting with the local section of the American Institute of Electrical Engineers and the Rochester Engineering Society, J. O. Perrine, of the American Telephone and Telegraph Company, presented his paper on "Waves, Words, and Wires."

February 10, 1939.

San Francisco

"Some Developments in Radio Preselectors and Automatic Tuners," were discussed by H. F. Elliott, consulting engineer for Motorola.

Various methods in push-button tuning were described. He then discussed and demonstrated a clock-controlled preselector which permitted programs to be selected for twenty-four hours in advance. Program changes were possible at fifteen-minute intervals which requires ninety-six selector elements to cover the twenty-four-hour period.

January 18, 1939—F. E. Terman, chairman, presiding.

W. G. Wagener, of Heintz and Kaufman, led a discussion of the "Review of Ultra-High-Frequency Vacuum-Tube Problems," by B. J. Thompson which was published in the October, 1938, issue of the *RCA Review*.

February 1, 1939—James Sharp, chairman, Seminar Committee, presiding.

"Facsimile Broadcasting" was the subject of a paper by Norman Webster, chief engineer of the McClatchy Broadcasting Company. RCA equipment was used in the broadcast facsimile service which was described. The scanning machine was of the conventional rotating-drum type. The scanning head traverses the length of the copy at a speed which produces 125 lines per inch. The light source is focused on the paper to a rectangular spot 0.008 inch by 0.003 inch. The reflected light actuates a phototube which through an amplifier and modulator, amplitude-modulates a 3200-cycle carrier wave. This carrier and its side bands can be transmitted over a standard broadcast system. Carbon-paper recording is used, the white recording paper and carbon paper being passed over a drum having a raised helical ridge on its surface. This drum is rotated in synchronism with the scanning drum. The received

signals operate a printer bar which pinches the carbon paper against the record paper at a point where it intersects the raised helix.

A 345-foot roll of white record paper and a 95-foot roll of carbon paper permit a month's operation on a ten-page-per-day schedule. Each page is $8\frac{1}{2}$ by 12 inches and requires approximately twenty minutes for transmission.

It is possible to reproduce half tones as well as line drawings. At the present time, eight pages of condensed copy and cuts are being transmitted between midnight and 3:10 A.M. from KFBK in Sacramento and KMJ in Fresno, California.

February 15, 1939—F. E. Terman, chairman, presiding.

Seattle

J. R. Tolmie, an engineer of the Pacific Telephone and Telegraph Company, presented a paper on "Transmission of Colored Photographs."

Either wire or radio transmission of colored photographs may be accomplished by transmitting three black-and-white prints. These prints are made from each of three negatives which have been exposed through color filters. Each received print could be made on one of the special relief films used in preparing colored photographs. The transmission system is the same as is used now for black- and white-picture service.

At the transmitting end of the telephoto system operated by the American Telephone and Telegraph Company, a 2400-cycle pulsating light beam 0.01 inch square moves axially along a revolving cylinder around which is fastened a photograph to be transmitted. The rate of motion is such as to give 100 lines per inch. The reflected light from a scanning beam actuates a phototube, the output of which passes through as 1200- to 2500-cycle band-pass filter, a frequency equalizer, an amplifier, and onto the telephone line. At the receiving end the signals are passed through another similar band-pass filter, rectified and passed through a 1200-cycle low-pass filter. The resulting signal after further frequency equalization operates a single-ribbon light valve which varies the width of a light beam similar to that at the transmitter. This light beam moves synchronously along the axis of another revolving drum carrying sensitized photographic paper.

An electrical analogy of three-color-separation photography was presented. An alternator was substituted for the light source, electric waves for light waves, band-pass filters for the color filters, and band attenuators for the complementary color dyes.

P. M. Higgs, professor of physics at the University of Washington, presented a paper on "The Production of Colored Photographs by Three-Color Separation." He discussed the "wash-off relief" process, demonstrating each part of the process following the printing of the relief films. The color-band response of each filter and dye was demonstrated by intercepting the spectrum reflected from a diffraction grating onto a screen. In this process, each of three negatives exposed respectively through red, green, and blue filters, was used to make a positive black-and-white print on and through the back of a special film having its emulsion suspended in a yellow light-attenuating gelatin.

Each film, which after development will have its silver image varying in depth from the film support according to exposure, is run through processes in which the gelatin is hardened only where there is metallic silver, the silver image is oxidized to silver chloride, the silver salts are fixed out, and the film washed to remove the fixing solution. Each resulting matrix which now consists only of a film supporting a clear gelatin of varying thickness is dyed a color complementary to that of the filter through which the respective negative was made, rinsed in dilute acetic acid, squeegeed in register onto a mordanted gelatin-coated paper, placed under pressure, and separated after all the respective dye is transferred. The three images, blue-green, magenta, and yellow, respectively, superimposed in register on the gelatin-coated paper, form the colored photograph.

February 17, 1939—T. M. Libby, acting chairman, presiding.

Toronto

"Recent Developments in Radio Receiving Tubes" were discussed by R. M. Wise, chief radio engineer of the Hygrade Sylvania Corporation.

The development of battery-type receiving tubes starting with the original tungsten filament and progressing through the thoriated-tungsten to the oxide-coated cathode was outlined. An oxide-coated straight-through filament for direct operation from a single dry cell has been developed. Because the filament is not of the V-type clearances of surrounding elements have been reduced. An increase in microphonism has resulted but not sufficiently serious to require a modification of design.

Curves were shown of the performance of a single six-inch dry cell when supplying current to the filament of these new tubes.

A comparison of the transconductance and interelectrode capacitance of the 1.4-volt tubes compared with the previously used 2-volt design showed the new tubes to be more effective even at their reduced filament consumption. Improved loudspeaker design permits satisfactory performance in an ordinary-sized living room with only a 75-milliwatt-output tube. Manufacturing problems encountered in the production of these tubes on a commercial scale were discussed.

The Loctal-type of tubes was described. A ring-seal arrangement permits the wires which form the airtight seal with the glass envelope to act also as the terminal pins. A shielding method has been developed for isolating the grid, the lead of which does not go to a top cap.

Samples of the various types of tubes were available for inspection.

January 9, 1939—R. C. Poulter, chairman, presiding.

F. S. Goucher of Bell Telephone Laboratories, presented a paper on "The Microphone and Research." In it Dr. Goucher presented the same general material as was given before the Montreal Section on February 9. A report of this appears under that section name in this issue.

This meeting was held jointly with the local section of the American Institute of Electrical Engineers and the Bell Telephone Society.

February, 13, 1939—R. C. Poulter, chairman, presiding.

Washington

"Applications for Ultra-High-Frequency Transmitters for Relay Broadcast Purposes," was presented by D. O. Hunter, studio engineer of the National Broadcasting Company.

He described various types of portable transmitters including the "beer-mug," pack set, and general utility types. Several types of portable cue and relay program receivers were also described. The paper was concluded with a demonstration of the "beer-mug" transmitter. Various pieces of equipment were available for inspection.

The second paper presented was by F. M. Ryan of the American Telephone and Telegraph Company, who spoke on "Radio Equipment for Telephone Communications in Emergencies."

It included a recently developed portable transmitter useful in re-establishing telephone communication during emergencies. Details of the equipment and circuits were given.

W. M. Swingle, transmission and outside plant engineer for the Chesapeake and Potomac Telephone Company of Virginia, commented on a motion picture which illustrated the procedure followed in starting up and operating the equipment.

The transmitter and receiver units with their associated controls and gasoline-engine-driven power source were displayed.

The paper was followed by the showing of several sound films taken after the New England hurricane disaster of last Fall.

The meeting was held jointly with the local section of the American Institute of Electrical Engineers.

February 13, 1939—Gerald C. Gross, chairman, presiding.

Membership

The following indicated admissions to membership have been approved by the Admissions Committee. Objections to any of these should reach the Institute office by not later than April 29, 1939.

Admission to Associate (A), Junior (J), and Student (S).

Adams, R. L., (S) 598 Williams St., Atlanta, Ga.
Ahrens, G. C., (A) 124–03—109th Ave., South Ozone Park, L.I., N. Y.
Algor, M. M., (S) 120 Willow St., Fair Haven, N. J.
Alward, P. B., (S) 407 W. South St., Angola, Ind.
Ambos, C., (A) c/o John E. Fast & Co., 3123 N. Crawford Ave., Chicago, Ill.
Ankrum, P. D., (A) 3514 Lafayette St., Fort Wayne, Ind.
Arnott, R. F., (A) 25 Glenwood Rd., Upper Montclair, N. J.
Baba, A., (A) 4885 Glencairn Rd., Hollywood, Calif.
Bergstrom, R. O., (S) 2627 Ridge Rd., Berkeley, Calif.
Bernard, W. B., (A) 307 Forest Ave., Marietta, Ga.
Boisvert, P., (A) 17 W. St. Joseph Blvd., Montreal, Que., Canada.
Bonadio, G. A., (A) 325 Winslow St., Watertown, N. Y.
Boyd, F. E., (S) 4030 Cold Spring La., Baltimore, Md.
Brown, K. C., (A) 18 Caythorpe Rd., Leeds 6, Yorks, England.
Brown, T. W., (S) 1328 Toledano St., New Orleans, La.
Buck, D. G., (A) 43 Hagen Ave., North Tonawanda, N. Y.
Chard, R. J., (S) Route 1, Box 309, Redwood City, Calif.
Christensen, P. C., (A) 552 Hamilton Ave., Palo Alto, Calif.
Clark, E. P., (A) U.S.S. *Philadelphia*, c/o Postmaster, New York, N. Y.
Clark, H. L., (A) Broadview Rd., West Richfield, Ohio.
Clement, E. M., (S) 709 W. Maumee St., Angola, Ind.
Collins, C. M., (S) 1144 E. Third South, Salt Lake City, Utah.
Comer, J. M., Jr., (A) 145 Columbia Dr., Decatur, Ga.
Coughlin, D. E., (S) 765—61st St., Oakland, Calif.
Day, J. V., (A) 18 E. Elm St., Chicago, Ill.
De Clercque, K. D., (J) 28213 Smith Rd., Inkster, Mich.
Dunn, E. F., (A) 88 Danson La., Welling, Kent, England.
Fachilla, M., (S) 404 N. Superior St., Angola, Ind.
Fox, E. B., (S) 1211 Jefferson St., Oakland, Calif.
Fox, J., (S) 720 Riverside Dr., New York, N. Y.
Frost, S. M., (S) 2315 Dwight Way, Berkeley, Calif.
Fry, B. L., (S) 527 Bay St., Santa Monica, Calif.
Fryer, P. W. F., (A) 25 Dollis Hill La., London N.W.2, England.
Gatti, W., (A) 1612—42nd St., Brooklyn, N. Y.
Haines, J. W., (A) 3224—16th St., N.W., Washington, D. C.
Hall, L. L., (A) P. O. Radio Branch, Armour House, London E.C.1, England.
Hammond, J. W., (A) 4407 Marble Hall Rd., Baltimore, Md.
Hancock, J. R., (A) 375 Lincoln Pl., Brooklyn, N. Y.
Hardenbergh, G. A., (S) 1301 E. California St., Pasadena, Calif.
Hardin, R. O., (A) Oak Park Dr., Knoxville, Tenn.
Hardland, L. S., (S) University Station, Grand Forks, N. D.
Harland, R., Jr., (S) 1021 W. Sixth St., Moscow, Idaho.
Harris, W. A., (S) 1426 E. Fifth St., Tucson, Ariz.
Harvey, J. P., (A) 10 Manor Rd., Farnborough, Hants., England.
Hayden, J. R., (A) 875 Michigan Ave., Columbus, Ohio.
Hayman, W. H., (S) 2411 Durant Ave., Berkeley, Calif.
Hiner, T. L., (A) Box 407, Pasadena, Tex.
Hollingsworth, G. L., (S) Crest Dr., Eugene, Ore.
Holzman, R., (A) 4518 St. Clair Ave., Detroit, Mich.
Houston, P. E., (A) 27 N.W. 60th St., Miami, Fla.
Ibuka, M., (A) Nippon Kon-on Co., Ltd., 564 4-chome, Kita-Shinagawa, Tokyo, Japan.
Ives, G. M., Jr., (A) 4221 Arthur Ave., Congress Park, Ill.
Jayavirsinhji, J. B., (S) 27 Regent St., London S.W.1, England.
Jones, O. J., Jr., (S) 227 Maple Ave., Grafton, W. Va.
Julian, R. S., (S) International House, Berkeley, Calif.
Kato, T., (S) 1547 Parker St., Berkeley, Calif.
Kleinhofer, B., (S) Tennis Ave., Ambler, Pa.
Konigsberg, S., (S) 3019 Deakin St., Berkeley, Calif.
Larsen, M. J., (A) Michigan College of Mining and Technology, Houghton, Mich.
Ledbetter, J. F., (A) USS *Skipjack*, c/o Postmaster, New York, N. Y.
Mac Donald, W. L., (S) 1799 Euclid Ave., Berkeley, Calif.
Marshall, F. M., (A) Box 674, Langley Field, Va.
Martin, H. L., (A) Minocqua, Wis.
McLaren, J. H., (A) Tilney St. Lawrence, King's Lynn, Norfolk, England.
Melton, E. L., (A) 1012–14 McGee St., Kansas City, Mo.
Meyer, M. A., (S) 14 Centre St., Cambridge, Mass.
Miller, J. W., (S) Johns Hopkins University, Box 667, Baltimore, Md.
Miyake, Y., (S) 59 Sarvataricho Kanagawaku, Yokohama, Japan.
Muchmore, R., (S) 2333 College Ave., Berkeley, Calif.
Mueller, G. E., (S) 608 W. 11th St., Rolla, Mo.
Newcomb, B. R., (A) 231 Pondfield Rd., Bronxville, N. Y.
O'Brien, R. S., (S) 2548 Cedar St., Berkeley, Calif.
Oniki, B., (S) 465 W. Fifth North St., Salt Lake City, Utah.
Ormontowicz, L. K., (A) Matejki 68, Torun, Poland,
Parker, J. D., (A) P.O. Radio Branch (WIA), Armour House, London E.C.1, England.
Parmelee, W. G., Jr., (S) Weatherford Hall, Corvallis, Ore.
Parry, W., (S) 1799 Euclid Ave., Berkeley, Calif.
Perkins, E. G., (A) 310 Cotton St., Greenwood, Miss.
Persons, C. B., (A) 4-B Hayes Ct., Superior, Wis.
Phillips, C. J., (A) Corning Glass Works, Corning, N. Y.
Pugsley, D. W., (A) 1766 E. Main St., Bridgeport, Conn.
Quraishi, A. H., (A) Sanda Kalan, Lahore, Punjab, India.
Ramiah, Y. V., (A) All India Radio, Egmore, Madras, South India.
Randles, W. C., (A) 2813 Clinton St., S., St. Petersburg, Fla.
Rebold, J. H., (A) 516 Flatbush Ave., Brooklyn, N. Y.
Reed, O. W. B., Jr., (S) 7601—16th St., N.W., Washington, D. C.
Reichert, W. L., (S) 1335 Fifth Ave., San Francisco, Calif.
Robinson, R. A., (S) 4187 Denker Ave., Los Angeles, Calif.
Roldan, A., (A) Ministerio de Guerra Secc. Radio, Bogota, Colombia.
Ross, K., (A) 63 Kingsley Ave., Rugby, England.
Rotkiewicz, W., (A) Grochowska 319 m. 12, Warszawa 4, Poland.
Rudd, W., (A) 836—11th Ave., Sidney, Neb.
Sambasivarao, S., (A) Veerabhadrapuram, Rajahmundry, East Godavari District, South India.
Schenck, R. L., (A) 5651 Hamilton Ave., Cincinnati, Ohio.
Schmidt, W. C., (A) 31 Sunset Ave., Newark, N. J.
Schneider, C. J., (S) Fleming House, 1301 E. California St., Pasadena, Calif.
Sensiper, S., (S) M.I.T. Dormitories, Cambridge, Mass.
Seymour, A. P., (A) 14 Hever Rd., Edenbridge, Kent, England.
Shelley, O. D., (J) 3224—16th St., N.W., Washington, D. C.
Sherry, F. E., Jr., (A) R.F.D., Marshfield, Mass.
Simons, B. H., (A) Bell Telephone Labs., Inc., 180 Varick St., New York, N. Y.

Spencer, F. L., (A) 20 Sunnydene Ave., Ruislip, Middx., England.
Stearns, H. M., (S) General Delivery, Stanford University, Calif.
Stewart, E. C., (A) 28 Roxborough St., E., Toronto, Ont., Canada.
Symonds, G. W., (A) 39 Wayne Pl., Nutley, N. J.
Tom, H., (A) 68 Mott St., New York, N. Y.
Vaksvik, A. J., (S) 721 S. Fourth St., Grand Forks, N. D.
Von Bergen, C. A., (S) 119—14th St., Oakland, Calif.
Wait, D. E., (S) 272 Amherst Ave., Berkeley, Calif.
Ward, F. R., (A) 4929 Darrah St., Philadelphia, Pa.
Warner, R. C., (S) 613 W. Pleasant St., Angola, Ind.
Weiss, H. G., (S) M.I.T. Dormitory, Cambridge, Mass.
White, F. C., (A) 114 N.E. 78th St., Miami, Fla.
Wiehr, J. A., (A) 144 Somerset St., Redwood City, Calif.
Wiley, H. T., (A) Box 653, Paris, Tex.
Winchell, R. W., (S) 612 N. Linden Dr., Beverly Hills, Calif.
Wolfskill, J. M., (A) 357 W. 10th St., Erie, Pa.
Wyeth, F. H., (A) 4901 Stenton Ave., Philadelphia, Pa.
Yosida, K. (A) JOAK Tokyo 2nd Broadcasting Station, Hatogaya-Machi Saitama-ken, Japan.
Zahl, H. A., (A) 320 Bath Ave., Long Branch, N. J.

Committee Personnel—1939

Admissions Committee

F. W. Cunningham, *Chairman*

H. H. Beverage	C. M. Jansky, Jr.
Ralph Bown	C. E. Scholz
Melville Eastham	J. S. Smith
J. F. Farrington	H. M. Turner
L. C. F. Horle	A. F. Van Dyck

Annual Review Committee

A. F. Van Dyck, *Chairman*

E. K. Cohan	H. S. Knowles
J. H. Dellinger	E. G. Ports
W. G. H. Finch	H. M. Turner
D. E. Foster	P. T. Weeks
Keith Henney	L. E. Whittemore

Awards Committee

Haraden Pratt, *Chairman*

H. H. Beverage	Melville Eastham
Ralph Bown	H. M. Turner

Board of Editors

Alfred N. Goldsmith, *Chairman*

R. R. Batcher	H. P. Westman, *ex officio*
P. S. Carter	L. P. Wheeler
F. W. Grover	L. E. Whittemore
B. E. Shackelford	William Wilson
K. S. Van Dyke	

Constitution and Laws Committee

H. M. Turner, *Chairman*

Austin Bailey	C. E. Scholz
Ralph Bown	B. J. Thompson
Alfred N. Goldsmith	H. R. Zeamans

Facsimile Committee

W. G. H. Finch, *Chairman*

J. C. Barnes	George Lewis
W. A. R. Brown	P. Mertz
J. L. Callahan	J. W. Milnor
J. V. L. Hogan	C. J. Young

Membership Committee

C. E. Scholz, *Chairman*

Nathaniel Bishop	A. F. Murray
E. L. Bowles	L. G. Pacent
I. S. Coggeshall	J. R. Poppele
E. D. Cook	F. X. Rettenmeyer
F. W. Cunningham	C. R. Rowe
H. F. Dart	B. Salzberg
Coke Flannagan	J. E. Smith
H. C. Gawler	F. E. Terman
R. M. Heintz	H. J. Vennes

J. S. Webb

(*Chairmen of Membership Committees of Sections, ex officio*)

New York Program Committee

I. S. Coggeshall, *Chairman*

H. A. Affel	J. F. Farrington
Austin Bailey	W. M. Goodall
R. R. Beal	Keith Henney
A. B. Chamberlain	G. T. Royden

Nominations Committee

C. M. Jansky, Jr., *Chairman*

W. G. Cady	Melville Eastham
F. W. Cunningham	B. J. Thompson

L. P. Wheeler

Papers Committee

William Wilson, *Chairman*

H. A. Affel	F. B. Llewellyn
Edmond Bruce	DeL. K. Martin
H. A. Chinn	H. R. Mimno
J. K. Clapp	A. F. Murray
T. A. M. Craven	H. O. Peterson
P. O. Farnham	R. K. Potter
E. B. Ferrell	H. M. Turner
E. L. Hall	P. T. Weeks
L. F. Jones	H. A. Wheeler

W. C. White

Publicity Committee

O. H. Caldwell	R. C. Poulter
Martin Codel	F. X. Rettenmeyer

K. B. Warner

Sections Committee

E. D. Cook, *Chairman*

I. S. Coggeshall	R. M. Heintz
Virgil M. Graham	J. H. Miller

C. E. Scholz

(*Chairmen of Sections, ex officio*)

Tellers Committee

Austin Bailey, *Chairman*

H. F. Dart	D. G. Fink

H. P. Westman, *ex officio*

TECHNICAL COMMITTEES

Electroacoustics Committee

H. S. Knowles, *Chairman*

L. B. Blaylock	George Nixon
J. T. L. Brown	Benjamin Olney
R. P. Glover	H. F. Olsen
Knox McIlwain	L. J. Sivian

Electronics Committee

P. T. Weeks, *Chairman*

L. B. Blaylock	F. B. Llewellyn
R. S. Burnap	G. F. Metcalf
E. L. Chaffee	A. F. Murray
H. P. Corwith	G. D. O'Neill
K. C. DeWalt	H. W. Parker
Ben Kievit, Jr.	B. J. Thompson
George Lewis	Balth. van der Pol

J. R. Wilson

Radio Receivers Committee

D. E. Foster, *Chairman*

E. H. Armstrong	C. J. Franks
C. R. Barhydt	Virgil M. Graham
L. B. Blaylock	David Grimes
R. I. Cole	D. E. Harnett
W. F. Cotter	R. S. Holmes
L. F. Curtis	D. D. Israel
Harry Diamond	H. O. Peterson
E. T. Dickey	A. E. Thiessen
H. B. Fischer	H. J. Tyzzer

Lincoln Walsh

Standards Committee

L. P. Wheeler, *Chairman*

W. R. G. Baker	H. S. Knowles
W. L. Barrow	R. M. Morris
H. H. Buttner	E. G. Ports
J. H. Dellinger	F. E. Terman
W. G. H. Finch	A. E. Thiessen
D. E. Foster	H. J. Vennes
Virgil M. Graham	P. T. Weeks
L. C. F. Horle	William Wilson

Television Committee

E. K. Cohan, *Chairman*

R. R. Batcher	A. G. Jensen
A. B. Dumont	I. J. Kaar
E. W. Engstrom	George Lewis
P. T. Farnsworth	H. M. Lewis
D. E. Foster	A. F. Murray
P. C. Goldmark	R. E. Shelby
T. T. Goldsmith, Jr.	

Transmitters and Antennas Committee

E. G. Ports, *Chairman*

Raymond Asserson	W. E. Jackson
L. B. Blaylock	J. F. Morrison
W. W. Brown	R. E. Poole
Harry Diamond	D. S. Rau
G. W. Fyler	J. C. Schelleng
Raymond Guy	P. E. Watson

J. E. Young

Wave Propagation Committee

J. H. Dellinger, *Chairman*

S. L. Bailey	G. D. Gillett
L. V. Berkner	H. R. Mimno
C. R. Burrows	K. A. Norton
T. L. Eckersley	H. O. Peterson
W. A. Fitch	Balth. van der Pol

Institute Representatives on Other Bodies

A.I.E.E.—Subcommittee on Radio of the Committee on Applications to Marine Work..........T. E. Nivison and J. L. Preston
American Documentation Institute..........C. M. Jansky, Jr.
Committee on Applied Physics..........William Wilson
Council of the American Association for the Advancement of Science..........J. C. Jensen
Engineering Index National Committee..........Melville Eastham
Joint Co-ordination Committee on Radio Reception of the N.E.L.A., N.E.M.A., and R.M.A..........C. E. Brigham
Liaison Committee on Aeronautic Radio Research..........F. M. Ryan (C. C. Shangraw, alternate)
National Advisory Council on Radio in Education..........Lloyd Espenschied, Alfred N. Goldsmith, C. W. Horn, L. M. Hull, and R. H. Marriott
New York City Advisory Board on Industrial Education..........H. P. Westman
Planning Committee, National Conference on Educational Broadcasting, American Council on Education..........C. M. Jansky, Jr., C. B. Jolliffe, and E. L. Nelson
Radio Broadcasting Committee, American Engineering Council..........Melville Eastham
U.R.S.I. (International Scientific Radio Union) Executive Committee..........C. M. Jansky, Jr.
U. S. National Committee, Advisers on Electrical Measuring Instruments..........Melville Eastham and Harold Olesen
U. S. National Committee, Advisers on Symbols..........L. E. Whittemore and J. W. Horton

American Standards Association

Board of Directors..........Haraden Pratt
Standards Council..........Alfred N. Goldsmith (H. P. Westman, alternate)
Board of Examination..........H. P. Westman
Electrical Standards Committee..........R. H. Manson (H. P. Westman, alternate)
Sectional Committee on Acoustical Measurements and Terminology..........E. D. Cook and Irving Wolff
Sectional Committee on Definitions of Electrical Terms..........Haraden Pratt
Subcommittee on Vacuum Tubes..........B. E. Shackelford
Sectional Committee on Electric and Magnetic Magnitudes and Units..........J. H. Dellinger
Sectional Committee on Electrical Installations on Shipboard..........I. F. Byrnes and V. R. Russ
Sectional Committee on Electrical Measuring Instruments..........Wilson Aull
Sectional Committee on Graphical Symbols and Abbreviations for Use on Drawings..........L. E. Whittemore (H. P. Westman, alternate)
Subcommittee on Communication Symbols..........H. M. Turner
Sectional Committee on Letter Symbols and Abbreviations for Science and Engineering..........A. E. Kennelly
Subcommittee on Letter Symbols for Radio Use..........H. M. Turner
Sectional Committee on National Electrical Safety Code, Subcommittee on Article 810, Radio Broadcast Reception Equipment..........E. T. Dickey (Virgil M. Graham, alternate)
Sectional Committee on Preferred Numbers..........A. F. Van Dyck
Sectional Committee on Radio..........Alfred N. Goldsmith, Haraden Pratt, and L. E. Whittemore
Sectional Committee on Radio-Electrical Co-ordination..........J. V. L. Hogan, C. M. Jansky, Jr., and L. E. Whittemore
Sectional Committee on Specifications for Dry Cells and Batteries..........H. M. Turner
Sectional Committee on Standards for Drawings and Drafting Room Practices..........L. E. Whittemore
Sectional Committee on Vacuum Tubes for Industrial Purposes..........B. E. Shackelford

Books

National Physical Laboratory, Collected Researches, Volume 24, Standards.

Published by His Majesty's Stationery Office, York House, Kingsway, London, W.C.2, England. 450 pages, 9½ inches by 12¼ inches. Price £1 2s. 6d, net.

This is the last of the "Collected Researches" to be published; their place is to be taken by collections of abstracts of papers published each year.

All of the ten papers relate mainly to fundamental standards and several have not previously been published.

Fundamental measurements of the volt, ampere, and ohm, of the capacitance and power factor of a mica condenser, and the measurement of high voltages, comprise the "electrical" contents of the book. A paper on instrument pivots and jewels would be of interest to those in the electrical instrument and meter field. The remaining papers concern the comparison of temperature scales and the relation between fundamental standards of length and the wavelength of light.

National Physical Laboratory, Abstracts of Papers, 1937.

Published by His Majesty's Stationery Office, York House, Kingsway, London, W.C.2, England. 71 pages, 6 inches by 9⅝ inches. Price 1s. 0d. net.

This is the second of a series of pamphlets giving abstracts of all papers contributed by the National Physical Laboratory to the scientific and technical press or issued as official publications. It covers all papers published during 1937, the previous report being for 1936.

The radio section abstracts twelve papers, half of which are on wave propagation studies, two on direction finding, two on vacuum tubes, and the other two are on recording transient electrical phenomena and detecting insect larvae in timber.

Several of the papers under "Electricity" would be of interest to radio engineers.

An authors' index and subject index are included.

Complete Proceedings of the World Radio Convention.

Published by the Institution of Radio Engineers, (Australia), Box 3120, General Post Office, Sydney, N.S.W., Australia. About 600 pages, well illustrated, 8¾ inches by 11 inches. Price 21/.

From April 4 to 14, 1938, the Institution of Radio Engineers (Australia) held a World Radio Convention as part of the celebration of the 150th anniversary of the founding of that country. Over 50 papers

were presented and these are published in full in this book. They include contributions on acoustics, aerial systems, aircraft radio, broadcasting, communications, direction finding and navigation, measurements and instruments, receivers, television, valves, and wave propagation. In addition, information is given on the meetings themselves, the Institution of Radio Engineers (Australia) and its membership.

Fundamental Electronics and Vacuum Tubes, by Arthur Lemuel Albert.

Published by the Macmillan Company, New York, N. Y., 1938. 422 pages, 286 figures, 6¼ inches by 9¼ inches. Price $4.50.

This is strictly an engineering text intended primarily for undergraduate use. The treatment is straightforward and concise, the arrangement clear and teachable. It is well illustrated, clearly designed for and built around its teaching objective. The author makes frequent use of italics to emphasize the key word in the context and of heavy type for technical terms. Frequent reference is made to the bibliographies which occur at the end of each chapter, where more general texts including those on radio engineering as well as many original articles in the literature are listed. In place of the commonly used list of problems at the end of a chapter the present text contains "Suggested Assignments." These are of the problem sort, but less definite, in that the data are incomplete. In other words, the final concrete setting of the problem is left to the student. An especially commendable feature in the eyes of the reviewer is the author's care in giving the source of data used in his curves throughout the book, or the reference from which figures are taken when this is the case. But one misprint is found. The reviewer regrets that in a number of cases the phrasing used by the author is a little loose and a somewhat different choice of words would have been desirable for accuracy and clarity.

K. S. Van Dyke
Wesleyan University
Middletown, Conn.

Principles of Electricity and Electromagnetism, by Gaylord P. Harnwell.

Published by McGraw-Hill Book Company, New York, N.Y., 1938, 619 pages, 384 figures. Price $5.00.

This is an excellently written book such as many radio-physicists have probably often wished for—a treatise on classical electricity and magnetism—with a treatment of comparable grade of the newer communication subjects and a consideration of the experimental behavior of materials available.

The new textbook is of a grade comparable to those of similar title now in use in advanced undergraduate and graduate courses in American universities. It differs from the books most used at present in including much more experimental material while retaining all of the mathematical analysis. This makes the book of considerably greater size for the field covered. Also, much more of the material commonly thought of as pertaining to the electrical communication field has been included than has been done in other standard textbooks on electricity and magnetism. Thus there are chapters on thermionic vacuum tubes and vacuum-tube circuits, coupled circuits, filters and lines, as well as the more classical theory. Particularly to be noted for those interested in the communication field are sections on electric networks, multielectrode tubes, wave filters, class A, B, and C amplifiers, nonlinear oscillator theory, and chapters on non-ohmic circuit elements, chemical-, thermo-, and photoelectric effects and electrical conduction in gases.

In paying particular attention to the experimental aspect of the subject, the author has collected much material on the electrical and magnetic properties of matter. A chapter entitled "The Physical Characteristics of Dielectrics and Conductors" follows the first two chapters of the book which are devoted to a theoretical development of electrostatics. In this third chapter the characteristics of many insulating materials are to be found including many of recent development and importance. A later chapter on the magnetic properties of matter includes a section correlating the special ferromagnetic properties of materials.

Vector notation is used throughout; a brief treatment of vector theory is given in the Appendix; additional sections in the Appendix treat other mathematical tools, and the matter of units and standards. The author boldly departs from the present conventional system of units so as to be in line with the new absolute system adopted by the International Committee of Weights and Measures for use after January 1, 1940, in place of the present international system. Thus the reader must expect to find equations based throughout on the newton meter as equivalent to the joule rather than on dynes and centimeters. There is ample use of well-drawn figures and frequent reference to other texts and to original papers. Excellent sets of problems follow each chapter. The volume is in itself a complete textbook of a grade most suited to the graduate student in experimental physics.

The author's treatment is of the highest standard throughout. The selection of material for inclusion, especially the emphasis on the communication subjects and the choice of the new units, makes the book timely and, with its experimental emphasis, an especially valuable reference.

The reviewer finds a very few errors, perhaps insignificant in so large a work. On page 188, the title of the figure is probably meant to be "Circuits Using Thermo-Electric Junctions," instead of "Circuits Visiting etc." On page 471, in defining different orientations of quartz resonators, the accepted designations of X cut and Y cut have been interchanged. On page 84 the author wrongly defines the piezoelectric constant of quartz, which he states to be the ratio of charge to mechanical force. This is true for certain special cases, as in the longitudinal effect, a limitation which the author does not mention. The usual definition of polarization per unit stress is applicable to any piezoelectric effect. Dimensionally, coulombs per newton is correct for this constant, but in general the areas over which the coulomb and newton will be distributed are not the same.

K. S. Van Dyke
Wesleyan University
Middletown, Conn.

Educational Broadcasting, 1937.

Proceedings of the Second National Conference on Educational Broadcasting. Held in Chicago, Illinois, on November 29, 30, December 1, 1937. Edited by C. S. Marsh. Published, 1938, by the University of Chicago Press, Chicago, Illinois. 387 pages. Price $3.00.

This volume, appearing many months after the conference was held of which it is a record, is still of interest, largely because of the continuing question of the desirability of control or regulation of broadcasting in America.

The principal objective of the conference was "to provide a national forum where interests concerned with education by radio could come together to exchange ideas and experiences." The general plan for the two and one-half days of its duration included four general sessions with prepared addresses representing the industry, the audience, and education. There were two afternoons of discussion sections and a banquet with speeches on the general topic.

The conference was attended by nearly five hundred registrants, with a broad national representation—eleven college presidents and about two hundred other representatives largely interested in some phase of education—about seventy-five from other welfare, social, or national organizations, fifty-five representatives of the radio industry, and scattered groups of journalists, publishers, editors, advertisers, and federal and state government officials.

The volume is not of primary direct interest to the radio engineer as such. The advanced state of his art and his technical excellence seem to be granted by all speakers. Nor does the volume particularly concern the artist who appears in radio programs. His great success in entertain-

ing and in holding interest and again his technical excellence is granted. This is a volume which records the growing pains of the new public utility, the broadcast industry, and the inevitable conflict between the entrepreneurs who had the foresight to develop the industry and who built their own system and others who now feel shut out of the necessarily closed system.

The speeches delivered in the four general sessions and constituting the material of the present volume were in general carefully prepared, sometimes very witty and, to judge from the remarks of the chairmen, were in some cases delivered by persons particularly well studied in the art of talking before a microphone. It was, apparently, the opinion of one spokesman for informal lobby and dining room discussions that most of the prepared speeches were largely favorable to this American system and that the smoothness of the conference did not reflect a general satisfaction with the system as operated.

K. S. Van Dyke
Wesleyan University
Middletown, Conn.

Radio Troubleshooter's Handbook, by Alfred A. Ghirardi.

Published 1939 by Radio and Technical Publishing Company, New York, New York. 518 pages, 134 illustrations, 9 inches by 11¼ inches. Price $3.00.

This handbook, as its title implies, is intended primarily to aid the radio serviceman in quickly locating and remedying faults in broadcast receivers. There are 272 pages of "case histories" covering troubles persistently noted in the field in 3313 models of home and auto receivers of 177 different makes. These case histories include symptoms and remedies. The material is presented clearly and in a form well suited for ready reference. Prepared in the same manner are sections covering common troubles in home and auto receivers, and a compilation of data as to the correct intermediate frequencies used in over 15,000 models of superheterodyne receivers. There is valuable material dealing with the installation of auto receivers and the elimination of ignition and other noises peculiar to particular sets and cars. The servicing of portable sound recorders and intercommunicator systems also is covered. The various tubes used in broadcast receivers are listed in several ways for ready reference and equivalent and substitute tubes are indicated. There is also a directory of set, tube, and parts manufacturers; several short sections dealing with mathematical formulas and conversion tables used in radio work; RMA symbols and color codes, etc.

The completeness of the servicing information and the manner of its presentation should make this volume of unusual value to the serviceman.

John F. Farrington
Hazeltine Service Corporation
Bayside, L.I., N.Y.

Einführung in die Vierpoltheorie der elektrischen Nachrichtentechnik, by R. Feldtkeller.

Published in 1937 by S. Hirzel, Leipzig. 142 pages, 85 diagrams. Price 10 RM.

This booklet has been accorded high praise in German periodicals. It gives indeed a very lucid and systematic development of the general theory of four-terminal networks. The more advanced mathematical tools needed, as conformal mapping and some fundamental properties of matrices, are explained in a neat and simple way. All derivations are carried through in detail. Thus the author succeeds in removing the veil of mystery which seems to have obscured the laws of these electric quadripoles to the not mathematically minded.

The book is divided into six chapters. Chapter I gives some fundamental relations. Chapter II, the longest in the book, deals with linear symmetrical networks. Special stress is laid on the geometrical construction for input impedance from terminal impedance by means of the various pairs of quadripole constants. In chapter III the results are specialized for nondissipative networks. Chapter IV deals with linear unsymmetrical quadripoles; this term is used for networks which are equivalent to a T network with unequal arms. In chapter V matrices of four elements are introduced as the most general mathematical expression for four terminals. Whereas all the preceding chapters deal with passive networks only, the matrices can also represent networks which contain unilateral conductances, especially amplifying tubes in the linear range of operation. The concluding chapter develops the matrices for a number of networks with and without unilateral conductances by a very simple application of matrix algebra.

The volume does not give any numerical examples or practical applications of the theory. These will doubtless be found in a book on filter networks whose publication has been announced for January, 1939.[1]

Feldtkeller follows the recent trend of German technical writers to introduce, wherever possible, Germanic words instead of the more international terms of Latin and Greek origin. While this practice certainly enhances the readability for the German student, it makes the going difficult for the American reader even if he is equipped with a modern dictionary.

Hans von R. Jaffe
Wesleyan University
Middletown, Conn.

[1] R. Feldtkeller, Einführung in die Siebschaltungstheorie der elektrischen Nachrichtentechnik. 175 pp. Leipzig, 1939.

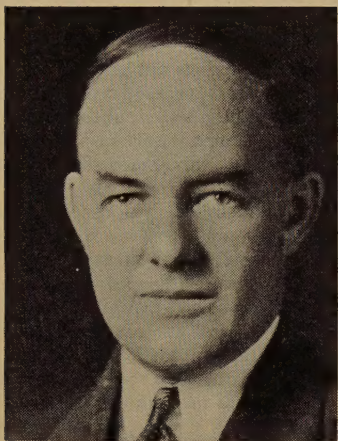
Bollettino del Centro Volpi di Elettrologia.

Published by the Volpi Center of Electrology, Vendramin Palace, Venice, Italy. Price, English edition, 30 lira per annum.

This quarterly bulletin made its appearance in the first quarter of 1938. It is devoted to electrical technology, and each issue contains papers dealing with various subjects in this field. The most important feature of the bulletin, however, is its abstracting service. In each issue approximately one hundred abstracts are so arranged that they may be cut to fit a standard 3- ×5-inch card file, with the Italian abstract on one side of the card and its English translation on the other. The subject classification of each abstract is given in the Decimal classification third German edition, Library of Congress fifth edition, and the American Engineering Index.

L. P. Wheeler
Federal Communications Commission
Washington, D. C.

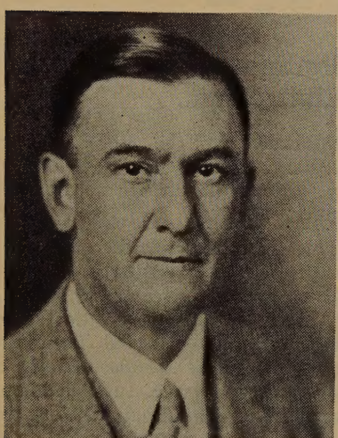
Contributors



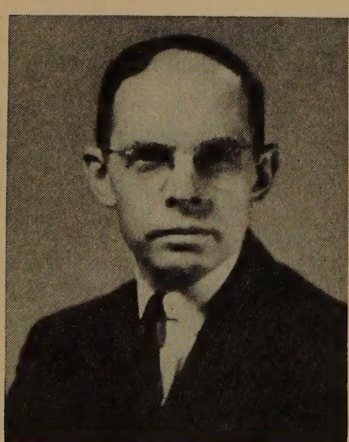
Clifford N. Anderson

Alda V. Bedford

A. C. Dickieson



Austin Bailey



R. S. Bair

Clifford N. Anderson (A'19, F'34) was born at Scandinavia, Wisconsin, on September 22, 1895. He received the Ph.B. degree from the University of Wisconsin in 1919 and the M.S. degree in 1920. From 1913 to 1917 Mr. Anderson was the supervising principal of schools at Amery, Wisconsin, and from 1917 to 1918 he served as an Ensign of Aircraft Radio in the United States Naval Reserve Force. From 1919 to 1920 he was an instructor in engineering physics at the University of Wisconsin, and from 1920 to 1921 he was in the standardizing laboratory of the General Electric Company at Lynn, Massachusetts. After spending the year 1921–1922 in Norway as a Fellow of the American Scandinavian Foundation, he entered the Department of Development and Research of the American Telephone and Telegraph Company where he stayed until 1934. Since then he has been with the Bell Telephone Laboratories.

❖

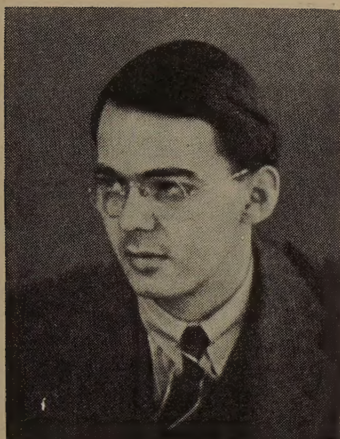
Austin Bailey (A'22, M'25, F'36) was born in Lawrence, Kansas, on June 9, 1893. He received the A.B. degree from the University of Kansas in 1915 and the Ph.D. degree from Cornell University in 1920. In 1918 he was made a Second Lieutenant in the Signal Corps of the United States Army and worked on the development of new radio equipment. Upon completion of his university work, following the war, he took a position as Superintendent of the Apparatus Division of the Corning Glass Works until the summer of 1921 when he resigned to be Assistant Professor of Physics at the University of Kansas. In June of 1922 Dr. Bailey accepted a position with the American Telephone and Telegraph Company, working on radio problems in the Department of Development and Research. In 1934 he was transferred to Bell Telephone Laboratories and in 1937 returned to the American Telephone and Telegraph Company, department of operation and engineering where he is continuing to work on radio services. Dr. Bailey became a Member of the American Institute of Electrical Engineers in 1937 and is a member of Sigma Xi and Alpha Chi Sigma.

❖

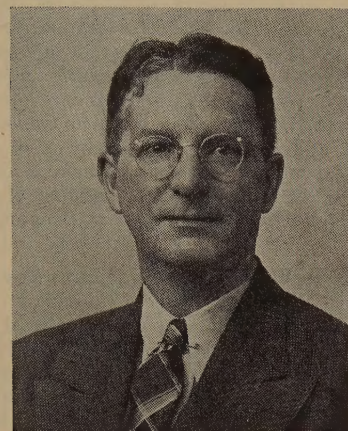
R. S. Bair (A'21, M'36) was born on May 1, 1896, at Wetmore, Pennsylvania. He received the B.S. degree in electrical engineering from Cooper Union in 1924. From 1916 to 1917 he was with the Western Electric Company Model Shop, and from 1917 to 1919 in the research and inspection division of the Signal Corps of the United States Army. After the war Mr. Bair was with the engineering department of the Western Electric Company from 1919 to 1925, and since 1925 he has been in the apparatus development department of Bell Telephone Laboratories. He is a Member of the American Institute of Electrical Engineers.

❖

Alda V. Bedford (A'31) was born in Winters, Texas, on January 6, 1904. He received the B.S. degree in electrical engineering from the University of Texas in 1925. While at the University he spent one summer with the Dallas Power and Light Company, and during the latter part of his school term he was engaged as assistant in the physics department. In 1925 Mr. Bedford joined the General Electric Company, starting in the general engineering



Stephen Doba, Jr.



John F. Farrington

H. B. Fischer

department and later transferring to the testing department and research laboratories, working on sound recording by film and disk, audio-frequency amplifiers, loud speakers, sound printers for film, and television. While in Schenectady he obtained the M.S. degree in electrical engineering from Union College. Since 1929 he has been employed in the laboratories of the RCA Manufacturing Company, first on disk sound recording and then on television.

❖

A. C. Dickieson was born at New York, New York, on August 16, 1905. He was with the Bell Telephone Laboratories from 1923 to 1929, the Fox-Case Corporation from 1929 to 1930, and since 1930 has been a member of the technical staff of Bell Telephone Laboratories.

❖

Stephen Doba, Jr., was born May 27, 1907, at New York, New York. Since 1926 he has been a member of the technical staff of Bell Telephone Laboratories.

❖

John F. Farrington (A'19, M'29, F'31) was born at New York, New York, in 1895. From 1907 to 1915 he was a radio amateur and radio operator in the Naval Auxiliary Service. In 1916 Mr. Farrington was an honor student at the Bliss Electrical school. He was a member of the research department of the Western Electric Company and Bell Telephone Laboratories from 1916 to 1929 doing development work on Government radio equipment during the war and contributing generally to the development of the Bell System trans-Atlantic and ship-to-shore radiophone services. From 1929 to 1931 he was engineer-in-charge of the radio department of International Communications Laboratories, and from 1932 to date he has been an engineer with the Hazeltine Service Corporation. He is a Fellow of the Radio Club of America.

❖

H. B. Fischer (A'25) was born in Wisconsin on June 26, 1902. He received the B.S. degree from the University of Wisconsin in 1924. From 1924 to 1925 Mr. Fischer was in the engineering department of the Western Electric Company, and since 1925 he has been with Bell Telephone Laboratories.

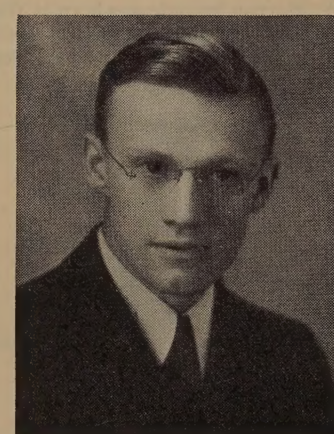
❖

G. L. Fredendall (A'26) received the Ph.D. degree from the University of Wisconsin. From 1931 to 1936 he was at the University teaching electrical engineering, mathematics, and doing research work in mercury-arc phenomena. Since 1936 he has been with the RCA Manufacturing Company engaged in television research.

❖

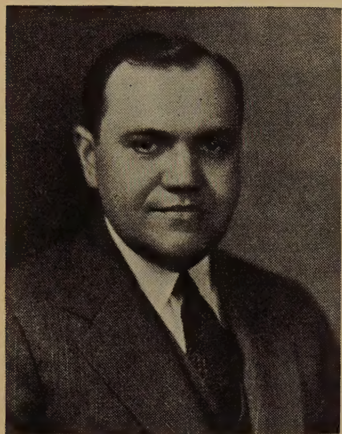
Harold M. Pruden was born November 3, 1899, at Basking Ridge, New Jersey. He is a licensed engineer in New York state. In 1917 Mr. Pruden was a radio operator with the Marconi Company, and from 1919 to 1925 he was in the engineering department of the Western Electric Company. Since 1925 he has been with the Bell Telephone Laboratories, engaged in circuit design of toll systems, including radio switching and signaling systems.

❖



G. L. Fredendall

Harold M. Pruden



W. MORGAN SWINGLE

W. Morgan Swingle was born at Washington, D. C., on June 1, 1904. He received the B.S. degree in electrical engineering from Massachusetts Institute of Technology in 1928. Since his graduation he has been in the engineering departments of several of the telephone companies in the Chesapeake and Potomac group. Since 1937 Mr. Swingle has been transmission and outside plant engineer of the Chesapeake and Potomac Telephone Company. He is an Associate member of the American Institute of Electrical Engineers.

❖

S. B. Wright (A'36) was born November 5, 1897, at Baltimore, Maryland. He received the M.E. degree in electrical engineering from Cornell University in 1919. He was a student engineer with the American Telephone and Telegraph Company in 1919, and later in the year became a telephone engineer in the department of development and research where he remained until 1934 when he took his present position as a member of the technical staff of Bell Telephone Laboratories. Mr. Wright is a member of Tau Beta Pi and the American Institute of Electrical Engineers.

❖

S. B. WRIGHT

For biographical sketches of T. R. Gilliland, S. S. Kirby and Newbern Smith, see the PROCEEDINGS for January, 1939.